KEITHLEY
CATALOG
91-92

Test & Measurement

1991–1992 Catalog and Reference Guide

General Measurements

Sensitive Measurements

Semiconductor Measurements

Scanners & Switches

Sources

LCZ Meters

Multifunction Synthesizers

Accessories

Joseph F. Keithley

KEITHLEY INSTRUMENTS

Contents

NEW PRODUCTS 2

INDEX: General 10

INDEX: Numerical 11

Upgrade Chart 13

Available Literature 14

Customer Service 15

MEASUREMENTS:
An Introduction 17

SELECTOR GUIDES

Digital Multimeters 20

Temperature Measurements 44

Electrometers 48

Picoammeters 48

Switching Mainframes 111

Switching Cards 116

Sources 140

Accessories:

- DMM Function Options 164
- Interfaces and Outputs 165
- IEEE-488 Interfaces and Software 167
- Test Leads and Probes 172
- Cables 176
- Connectors and Adapters 183
- Test Fixtures 191
- Calibration, Maintenance, Spare Parts 196
- Power 199
- Racks and Rack Kits 200
- Carrying Cases 204

GENERAL MEASUREMENTS 19
Digital Multimeters
High Resolution Digitizer
System Thermometer
Counter/Timer

SENSITIVE MEASUREMENTS 47
Electrometers
Picoammeters
Nanovoltmeters
Micro-ohmmeter

SEMICONDUCTOR MEASUREMENTS 75
I-V Measurements
Quad Voltage Source
Source-Measure Units
C-V Measurements
Hall Effect Measurements

SCANNERS AND SWITCHES 109
Scanner Mainframes
Switching Matrix
Switching Cards
Matrix Cards

SOURCES 139
Programmable Current and Voltage Sources
High Voltage Power Supply

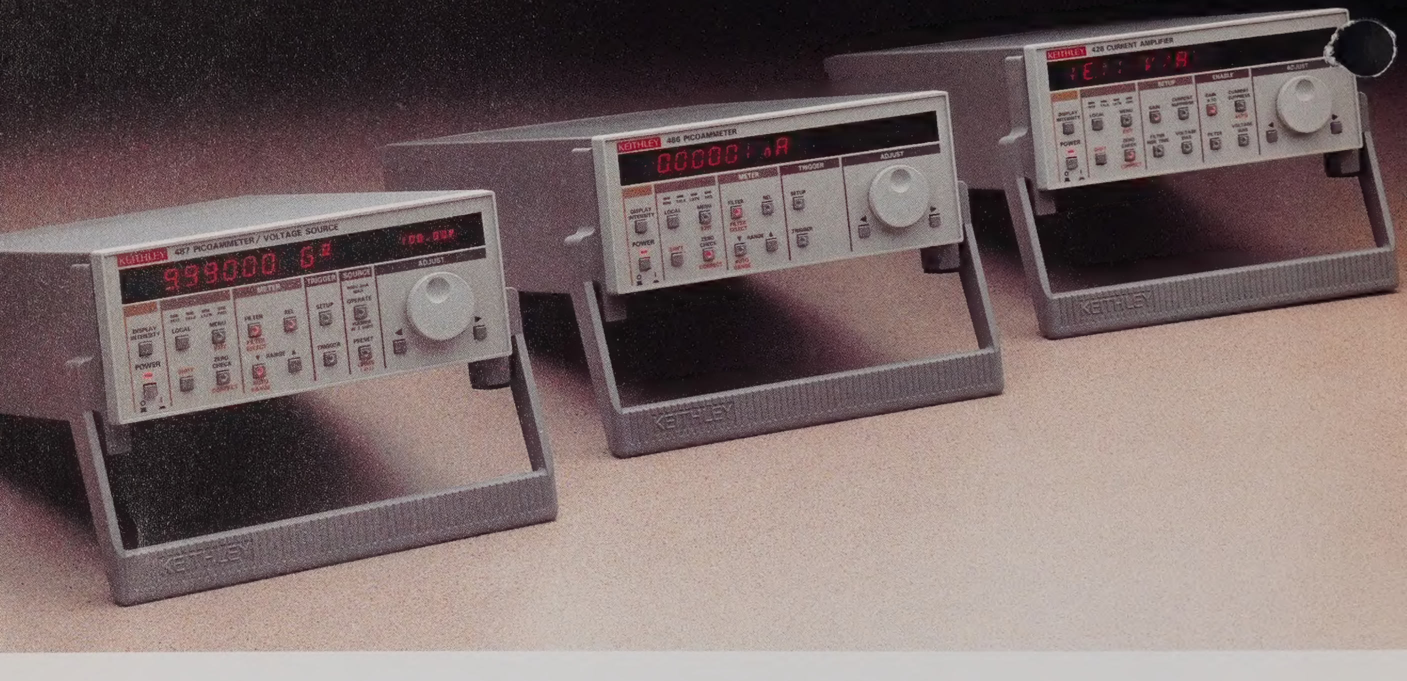
AC INSTRUMENTS 155
LCZ Meters
Multifunction Synthesizers

ACCESSORIES 163
Function Options
Interfaces & Outputs
Test Leads & Probes
Cables
Connectors & Adapters
Test Fixtures
Calibration
Spare Parts
Rack Mount Kits
Carrying Cases

OTHER KEITHLEY DIVISIONS 205
Keithley MetraByte/Asyst/DAC
Keithley Systems Division
Keithley Radiation Measurements Division

ORDERING AND OTHER INFORMATION 221
How To Order
Warranties
Sales Representatives
Glossary

New Products



487: Picoammeter/Source

- **Resistivity Measurements <1Ω to >10¹⁶Ω**
- **± 500V Source**
- **10fA Sensitivity**
- **180 Readings per Second**
- **5½-Digit Resolution**

The new Model 487 Picoammeter/Voltage Source is specifically designed for accurate measurement of low current and very high resistance. This compact unit will make current measurements from 10fA to 2mA and will program reading intervals from 10ms to1000ms.

Two voltage source ranges are available: a 500V range with 10mV resolution and a 50V range with 1mV resolution. The 487 will source up to 500V, measure the current, then instantly calculate the resistance. The unit has two displays: one for voltage sourcing and another for current or resistance.

486: Picoammeter

- **10fA Sensitivity**
- **180 Readings per Second**
- **5½-Digit Resolution**
- **Autoranging**
- **500-Reading Memory**

The new Model 486 Picoammeter is designed for low current applications where very fast reading rates must be maintained. With 5½-digit resolution, the Model 486 is capable of full-scale measurements from 2nA to 2mA with 10fA sensitivity on the lowest range. At 180 readings per second, this is the fastest picoammeter currently on the market.

An IEEE-488 interface and 500-reading data buffer simplify data handling tasks. All calibration adjustments are made on the front panel or over the IEEE-488 interface.

428: Current Amplifier

- **2μs Rise Time**
- **<1pA Noise**
- **10^{11}V/A Gain**
- **± 5V Bias Supply**
- **IEEE-488 Interface**

The new Model 428 Low Current Amplifier provides a high speed, low noise interface between low current sources and voltage measuring instruments. It achieves both fast rise times and very low noise levels. The gain of the Model 428 is adjustable in decade increments from 10^3V/A to 10^{11}V/A, with selectable rise times from 2μs to 300ms.

The 428 also offers automatic suppression of background current and a programmable ± 5V bias supply. This unit offers excellent results as a preamplifier to a digital oscilloscope, or to amplify small electron beam induced currents.

KEITHLEY INSTRUMENTS

New Products

KEITHLEY
213 QUAD VOLTAGE SOURCE
2361 TRIGGER CONTROLLER
+0.9000 A +15.0008 V

238: High Current ource-Measure Unit

- **1A, 110V Source and Measure**
- **10fA, 10μV Sensitivity**
- **DC, Pulse, Sweep Modes**
- **4-Wire Kelvin Connections**
- **1000 Source-Measurements per Second**

The new Model 238 Source-Measure Unit is a fully programmable instrument capable of sourcing and measuring voltage or current simultaneously. It is designed to function as four instruments in one: digital multimeter, electrometer, voltage source and current source. The Model 238 can source and measure voltage from 100μV to 110V and current from 100fA to 1A. It will complete up to 1000 source-measurements per second.

This unit is particularly useful in automated test equipment and will address a wide variety of applications, including the characterization of semiconductor devices, and measurement of leakage currents r resistivity.

213: Quad Voltage Source

- **GPIB-Controlled Voltage Bias**
- **4, 12-Bit Voltage Sources**
- **10mA per Channel**

The Model 213 Quad Voltage Source includes four fully independent channels, which provide up to ± 10V at 10mA of voltage bias to GPIB test systems. 12-bit source programmability provides voltage resolution down to 250μV/bit. The 213 works with SMUs and other precision sources and meters for biasing devices in multi-pin test systems.

2361: Trigger Controller

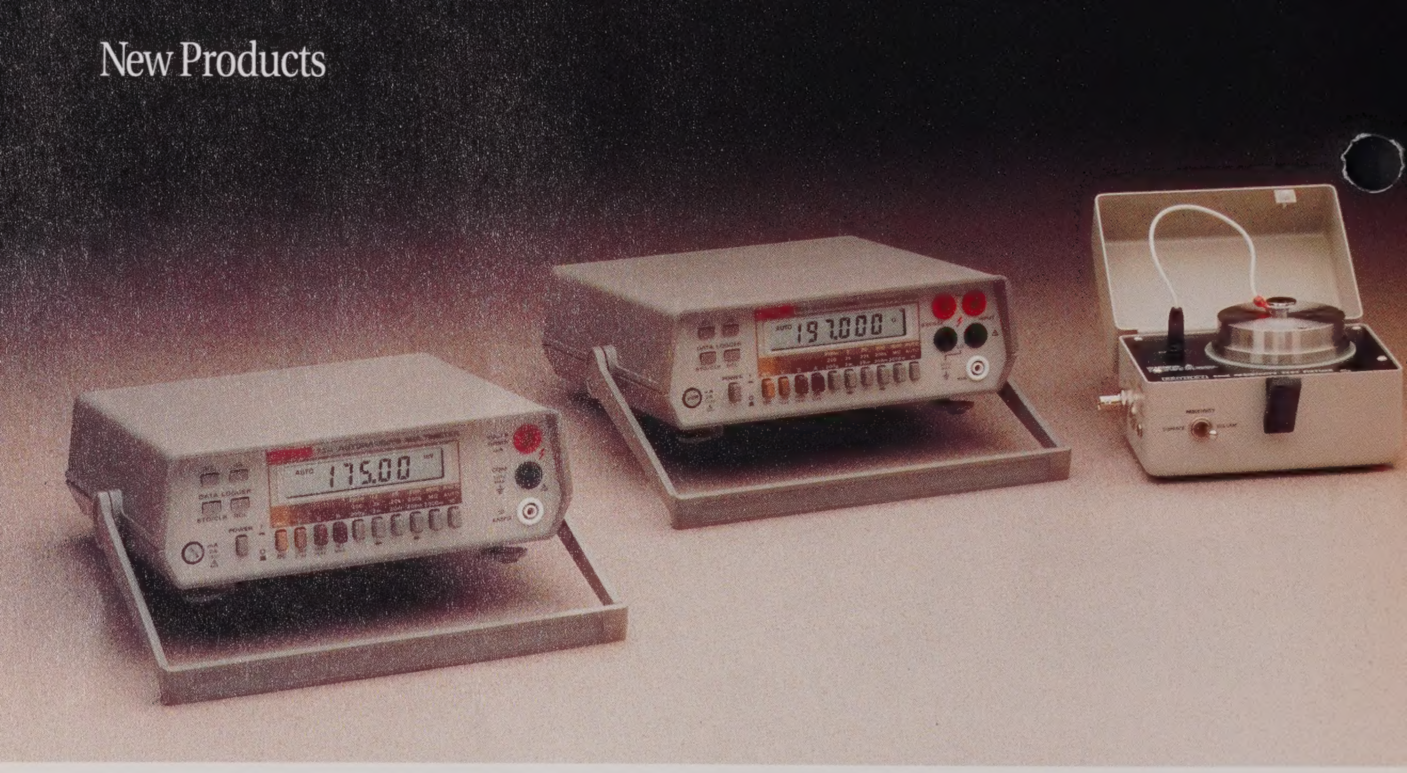
- **Triggers up to 6 Instruments**
- **Automatic Routing of Signals**
- **Speeds Multiple SMUs**

The Model 2361 Trigger Controller puts trigger routing under GPIB control by connecting the trigger inputs and outputs of up to six instruments. All triggers in the test system are passed through the 2361 to coordinate interaction between instruments, including source settling, measurement, and switch closure changes.

251: I-V Test Software

- **Interactive I-V Test**
- **10fA and 10μV Sensitivity**
- **Control Any GPIB Device**

The new Model 251 I-V Test Software offers interactive testing of current vs. voltage (I-V). It utilizes Keithley's SMUs to measure and display device characteristics such as I-V curve families, breakdown voltage, leakage current, DC or differential gain, and resistance, at currents from 10fA to 1A and voltages from 10μV to 1100V.



175A: 4½-Digit DMM

- **10μV, 10nA, 10mΩ Sensitivity**
- **Battery or Line Operation**
- **0.03% DC Accuracy**
- **Built-in Data Logger**

The new Model 175A Digital Multimeter offers 4½-digit resolution and IEEE-488 compatibility in a portable unit for bench or field applications. This DMM features current measuring capability up to 10A, resistance measurements of 10mΩ to 200MΩ, and a TRMS AC bandwidth of 100kHz.

The 175A has a 100-point memory that can store data at six different rates. A min/max reading hold feature stores the highest and lowest readings over time, and a relative reference feature zeros displays quickly for baseline comparisons. Users also can choose manual or autoranging modes on DC and TRMS AC volts, ohms, and dB functions.

197A: 5½-Digit DMM

- **1μV, 1nA, 1mΩ Sensitivity**
- **0.011% DC Accuracy**
- **TRMS AC Measurements to 100kHz**
- **100-Point Data Logger**

The new Model 197A Digital Multimeter is a five-function, IEEE-488 compatible DMM that features 5½-digit resolution and 0.011% DC accuracy. This portable unit offers 1μV, 1nA, and 1mΩ sensitivities for precise measurements in a wide range of applications.

The 197A can measure voltage up to 1000V and current to 10A. Resistance measurements can be made with either two-terminal or four-terminal techniques up to 220MΩ, and TRMS AC measurements to 100kHz. This DMM also features a built-in data logger that stores up to 100 readings, a min/max hold feature, relative reference, and digital calibration.

8008: Resistivity Test Fixtur

- **Measure Volume Resistivity**
- **Measure Surface Resistivity**
- **Wide Resistivity Range**
- **High Insulation Resistance**

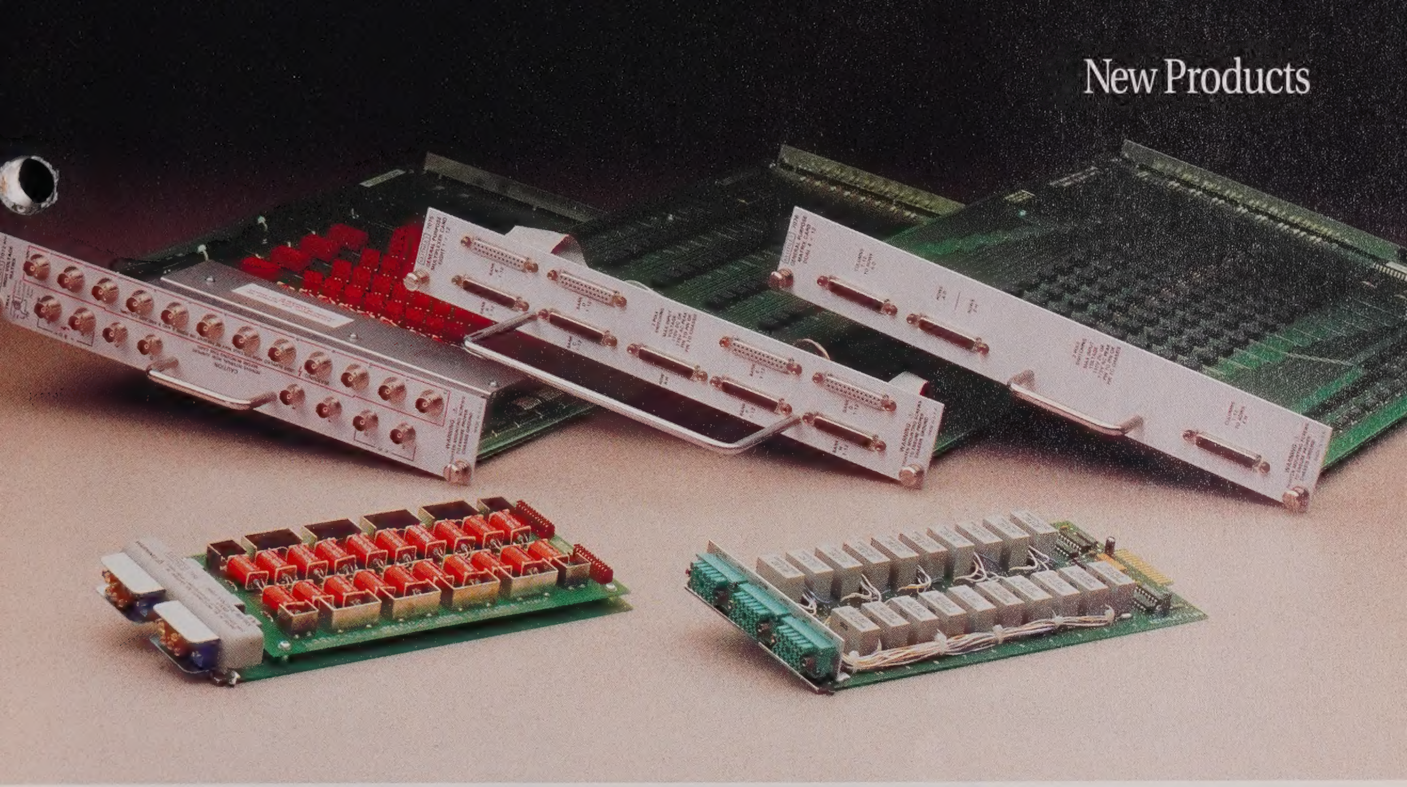
The new Model 8008 is a guarded test fixture for measuring volume and surface resistivities. It permits direct measurement of volume resistivity up to $10^{18}\Omega$/cm and surface resistivity up to $10^{17}\Omega$.

The 8008 accommodates sheet samples 2½ to 4 inches in diameter and up to ¼ inch thick. A uniform one pound pressure maintains good sample contact on smooth parallel samples.

The 8008 was specifically designed for use with the Model 487 Picoammeter/Source and Models 236, 237, and 238 SMUs.

KEITHLEY INSTRUMENTS

New Products



7072-HV: 8 × 12 High Voltage Semiconductor Matrix Card

- Two 1300V Paths
- Sub-Picoamp Current
- Six 200V, 20pA Paths
- Use With 237 SMU
- Measure C-V from DC to 1MHz
- 3-Lug Triax Connections

7075: Eight 1 × 12 2-Pole Multiplexer Card

- <5µV Voltage Offset
- <100pA Offset Current
- 30MHz Bandwidth
- 110V, 1A Signal Levels
- Low Cost
- 25-Pin D Connectors

7076: Dual 4 × 12 2-Pole Matrix Card

- <5µV Voltage Offset
- <100pA Offset Current
- 15MHz Bandwidth
- 110V, 1A Signal Levels
- Low Cost
- 25-Pin D Connectors

7153: 4 × 5 High Voltage Low Current Matrix Card

- 1300V Switching
- Sub-Picoamp Offset Current
- 2-Pole Switching
- Path Isolation $>10^{13}\Omega$
- Two-Pole Relays
- Mass Termination Connectors

7169: 20-Channel Form C Switch Card

- 20 Independent Relays
- Single-Pole, Double-Throw
- 500V Peak
- Mass Termination Connectors
- On-Card Bus
- Channel Interconnection

KEITHLEY INSTRUMENTS

KEITHLEY
182 SENSITIVE DIGITAL VOLTMETER
0.000022mV
Range 3mV
KEITHLEY
617 PROGRAMMABLE ELECTROMETER
1.6171 PA

182: Sensitive Digital Voltmeter

- **1nV Sensitivity**
- **5ppm Transfer Stability**
- **>10GΩ Input Resistance**
- **100 Readings Per Second**
- **6½-Digit Resolution**
- **3nV rms Noise**

The new Model 182 Sensitive Digital Voltmeter offers the highest accuracy available from any instrument for measuring extremely low voltages, 10mV or below. This programmable unit holds noise to just 15nV peak-to-peak, providing highly stable readings for low voltage applications. Reading rates up to 100 readings per second are possible with microvolt sensitivity.

The 182 offers high input resistance, greater than 10GΩ on all voltage ranges, which also helps ensure accuracy by minimizing loading effects. A special low thermal input connector and cable is used to maintain signal integrity. Up to 160dB of Common Mode Rejection is possible through a unique FET input design. This unit also has a 1024-reading memory to store data for processing by its built-in statistical functions: maximum, minimum, average, and standard deviation.

With 6½-digit resolution, the Model 182 features a combination of sensitivity and accuracy superior to high-resolution digital multimeters costing several times the price.

617-HIQ: Electrometer/Source

- **Charge Measurements to 20μC**
- **Built-in V Source**
- **Full Autoranging**
- **Built-in V-Ω Guard**
- **IEEE-488 Interface**
- **Data Storage**

The new Model 617-HIQ Electrometer/Source is a modified version of Keithley's popular Model 617, with charge measuring capabilities from 20nC to 20μC full scale. This programmable unit was specifically designed to measure charge on toners. It is a sensitive, versatile, 4½-digit, 7-function instrument which includes a bi-polar 100V voltage source, a decade current source, IEEE-488 interface, and outstanding low current accuracy specifications.

The Model 617-HIQ is among the most sensitive measuring instruments available, with current measuring capabilities to 1fA, voltage to 200V, and resistance to $10^{16}\Omega$. The unit is capable of storing 100 data po[illegible] with min/max readings programmable from the front panel or over the IEEE bus.

KEITHLEY INSTRUMENTS

925: Hall Effect Systems

- **Turnkey System**
- **Hall and van der Pauw Techniques**
- **Carrier Concentrations and Mobility**
- **Test GaAs, III-V and II-VI Materials**
- **Dual Temperature Analysis**

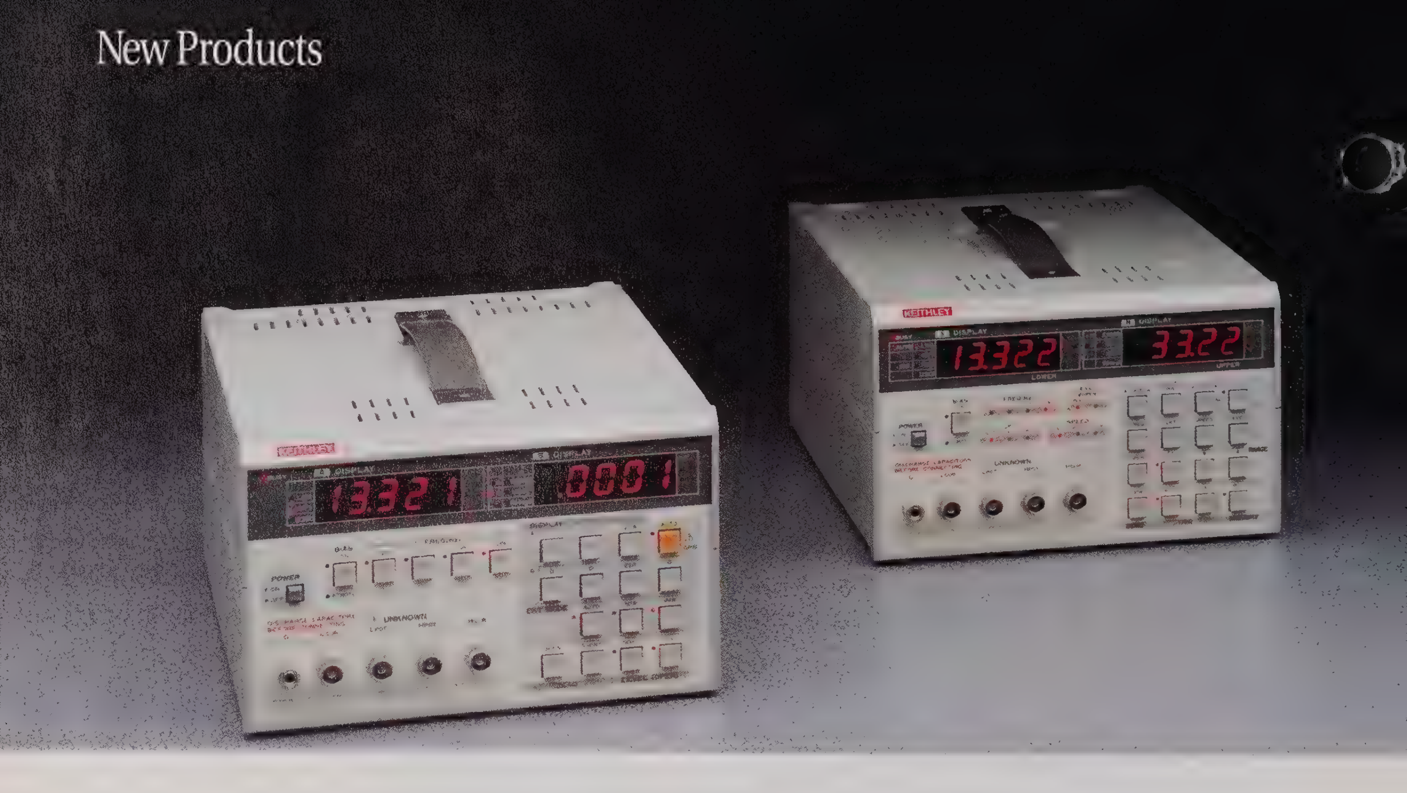
The new Models 925A and 925B Hall Effect Systems offer highly accurate Hall Effect and related measurements of both high and low resistivity materials. The 925A is a fully configured room temperature system with a built-in electromagnet, measurement instrumentation, and full menu-selectable software. The 925B is a dual-temperature system with the addition of a liquid nitrogen [illegible]K dewar. Both systems measure van der Pauw resistivity and Hall coefficient of a fixed sample and translate the information into carrier concentration and mobility.

The Model 925 uses a sensitive DC measuring scheme to provide 40nV sensitivity per stored data point. The system conducts 24 measurement points per cycle, with up to 100 cycles per sample for very precise readings. The resistance range can correspond to carrier concentrations ranging from $10^9/cm^3$ to more than $10^{22}/cm^3$.

926: Differential Hall Effect Profilers

- **Turnkey System**
- **Hall as a Function of Depth**
- **Controlled Etching**
- **Carrier Concentration & Mobility**
- **Dual Temperature Analysis**

The new Models 926A and 926B Differential Hall Effect Profilers offer the same highly accurate measurements as the 925 Hall Effect Systems, plus additional etching capability. The 926A incorporates a controlled chemical etch technique to remove thin layers from a semiconductor surface. By etching and measuring multiple layers, this turnkey system will calculate carrier concentrations and mobility that may vary by depth. The 926B offers the same features with room temperature and 77K capabilities.



3321: LCZ Meter

- 0.1% Accuracy
- Low Cost
- Automatic Function and Circuit Selection
- Four Test Frequencies to 100kHz

The new Model 3321 is a high-precision LCZ Meter designed for easy operation. Measurement complexity is greatly reduced by using the powerful function and circuit selector that automatically gives the appropriate reading by simply connecting the device under measurement. GPIB is standard.

3322: LCZ Meter

- **0.1% Accuracy**
- **Automatic Function and Circuit Selection**
- **Binning and Deviation Capability**
- **Eleven Frequencies to 100kHz**

The new Model 3322 is a multifunction LCZ Meter that offers outstanding performance in the characterization of components and materials. It features a basic accuracy of 0.1%, resolution of 4½ digits, a wide frequency range of 11 points up to 100kHz, two measurement signal levels, automatic setting, superimposed DC bias, and GPIB interface. This compact unit also has a component selection function, deviation display function, and front panel setup memory, making it a powerful tool for use in applications ranging from R&D to production line and inspection measurements.

Test Fixtures and Leads for LCZ Meters

(Optional Accessories)

The Models 3321 and 3322 may be combined with four types of measurement fixtures, including direct connections, four-terminal alligator, Kelvin, and SMT devices to accommodate a variety of DUT configurations.

New Products

3930A: Multifunction Synthesizer

- **0 – 1.2MHz with 0.1mHz Resolution**
- **5ppm Accuracy**
- **11-Digit Resolution**
- **30V p-p**

The new Model 3930A Multifunction Synthesizer is a general purpose Direct Digital Synthesizer with a frequency range from 0.1mHz to 1.2Mhz. It features synthesized operation in any operating mode, with a frequency accuracy of ± 5ppm. In addition, multifunction sweep, burst, gate, variable duty ratio, amplitude modulation and five types of waveforms are available.

3933A: Phase Shifter

The new Model 3933A Phase Shifter can be combined with the Model 3930A to configure a multiphase oscillator with up to six variable phase synchronized signals. It provides independent settings of output voltages, waveforms, duty cycle, and phase sweep.

3940: Multifunction Synthesizer

- **0 – 20MHz with 0.1mHz Resolution**
- **5ppm Accuracy**
- **12-Digit Resolution**
- **Arbitrary Waveforms**

The new Model 3940 Multifunction Synthesizer offers Direct Digital Synthesis with the inherent advantages of superior frequency accuracy and phase continuity. Maximum frequency is 20MHz with 0.1mHz of resolution and ± 5ppm accuracy. Arbitrary waveforms captured with a digital storage oscilloscope or data recorder can be easily down-loaded via computer and output through the Model 3940. Additional functions include trigger/burst/gate functions, a variety of sweep functions, synchronous-operation capability, and external signal summation. In addition, a built-in sub-synthesizer provides the functionality of two units in one.

3910: Multifunction Synthesizer

- **0 – 1.0MHz with 0.1mHz Resolution**
- **30ppm Accuracy**
- **11-Digit Resolution**
- **20Vp-p**

The new Model 3910 Multifunction Synthesizer offers the precision inherent in Direct Digital Synthesis, but at the price of standard function generators. The frequency range is 0.1mHz to 1.0MHz for sinewaves and squarewaves (fixed or variable duty cycle), and 0.1mHz to 100kHz for triangle and up/down-ramping sawtooth waveforms. Accuracy is held to ± 30ppm over the entire frequency range.

KEITHLEY INSTRUMENTS

Index General

A
AC MEASUREMENTS 155
ACCESSORIES 163
Adapters 183
Application Notes 14

B
Battery Packs 199
Battery Eliminator 199

C
C-V Measurements 88-100
Cabinets 200
Cables 176
Calibration 195
Calibration Sources 100, 197
Calibrator/Source 153
Capacitance Measurements 93, 96
Capital Equipment Corp. Products 167
Carrying Cases 204
Charge Measurements 53-65
Coaxial Cable 176
Computer Interfaces and Software 167
Connectors 183
Counter/Timer 45
Current Amplifiers 53-65
Current Shunt 172
Current Sources 139
Customer Service 15

D
Data Acquisition & Control Modules 206
Data Acquisition & Control Software 206
Data Acquisition & Control Systems 206
Digital Multimeters (DMMs) 19-42
Digitizer 36

E
Electrometers 47-59
Equipment Cabinets 200
Extended Warranty Information 232

F
Function Options 164
Function Synthesizers 158-161

G
GENERAL MEASUREMENTS 19-46
Glossary 222-227
Graphics Software 170

H
HALL EFFECT MEASUREMENTS 101-108
High Current SMU 84
High Input Impedance Amplifiers 53-65
High Resistance Measurements 53-65
High Resolution Digitizer 36
High Voltage Sources 139
High Voltage SMU 84

I
I-V Measurements 77-87
I-V Software 77
IEEE-488 Controller Boards 167
IEEE-488 Controller Software 167
IEEE-488 Interfaces 167
IEEE-488 Cables 176
Input Cables 176
Instrument Interfaces and Output Options 165
IOtech GP488B 171

K
Keithley MetraByte/Asyst/DAC 206
Keithley Radiation Measurements Division 218
Keithley Systems Division 214

L
Laboratory Software 206
LCZ Meters 155-157
Literature Available 14
Log Picoammeters 62
Low Current Measurements 53-65
Low Resistance Measurements 73
Low Voltage Measurements 66-72

M
Maintenance Kits 196
Matrix Switching 114-117
Measurements: An Introduction 17
Micro-ohmmeter 73
Multifunction Synthesizers 158

N
Nanovoltmeters 66-70
Nanovolt Source 72
Nanovolt Switch 127
Nanovolt System 72
New Products 2-9

O
Ohmmeters 20-42, 73
ORDERING INFORMATION 221
Output Options and Instrument Interfaces 165

P
Picoammeters 53-65
Power Options 199
Probes and Test Leads 172
Programmable DMMs 20
Programmable Electrometers 48
Programmable Sources 140
Programmable Switches 109-115

R
Racks and Rack Mount Kits 200
Radiation Measurements Division 218
Resistance Measurements 20-42, 73

S
Sales Representatives: International 229
Sales Representatives: U.S. 228
SCANNERS AND SWITCHING 109
Scientific Software 206
Selector Guide: Cables 176
Selector Guide: Connectors & Adapters 183
Selector Guide: DMMs 20
Selector Guide: Electrometers 48
Selector Guide: Function Options 164
Selector Guide: Interfaces & Outputs 165
Selector Guide: Picoammeters 48
Selector Guide: Power Options 198
Selector Guide: Racks and Rack Mount Kits 200
Selector Guide: Sources 140
Selector Guide: Switching Cards 116
Selector Guide: Switching Mainframes 111
Selector Guide: Temperature Measurements 44
Selector Guide: Test Fixtures 191
Selector Guide: Test Leads & Probes 172
SEMICONDUCTOR MEASUREMENTS 75-108
SENSITIVE MEASUREMENTS 47-74
Service Information 231
SOURCES 139-154
Source/Measure Units 84
Spare Parts Kits 196
Substitution List 13
SWITCHING 109-138
Switching Cards 116-138
Switching Mainframes 110-115
Systems Division 214
System DMMs 20
System Thermometer 43

T
Technical Data: DMMs 22
Technical Data: Low Current Measurements 49
Technical Data: Nanovoltmeters 66
Technical Data: Sources 142
Technical Literature 14
Temperature Measurements 43-44
Test Fixtures 191
Test Leads & Probes 172
Thermocouple Wire Kit 181
Thermocouple Thermometer 43
Triaxial Cable 176

U
Upgrade Chart 13

V
Voltage Measurements 20-42, 66-72, 84-91
Voltage Sources 84, 140

W
Warranty Information 232

New products are listed in bold.

Numerical Index

4-488-CEC-0M	IEEE-488, Serial Port, Parallel Port, without RAM Memory for IBM AT	168
4-488-CEC-1M	IEEE-488, Serial Port, Parallel Port, with 1MB Expanded RAM Memory for IBM AT	168
78	**Nanovolt Scanner System**	**72**
80	Hall Effect System	103
82	Simultaneous C-V System for HP Computers	88
82-DOS	Simultaneous C-V System for DOS Computers	88
82-PS/2	**Simultaneous C-V System for PS/2 Computers**	**88**

100

155	Null Detector/Microvoltmeter	71
169	Portable/Bench LCD DMM	42
175A	Autoranging Digital Multimeter (4½-digit)	39
177	Microvolt Digital Multimeter (4½-digit)	41
179A	TRMS Digital Multimeter, 20 Amp	41
181	Digital Nanovoltmeter	70
182	Sensitive Digital Voltmeter	68
193A	System DMM (3½- to 6½-digit)	34
194A	High Resolution Digitizer	36
195A	System DMM with Temperature	32
196	System DMM (3½- to 6½-digit)	27
197A	Autoranging Microvolt DMM (5½-digit)	30
199	System DMM/Scanner	24
199/1992	System DMM/Scanner w/8 Channel Scanner Option	25

200

213	**Quad Voltage Source**	**144**
213-CON	**Analog Output Connector**	**184**
213-RBN-2	**Card Edge Connector with 2m (6.2 ft.) Ribbon Cable**	**177**
220	Programmable Current Source	108, 146
220/617	**High Impedance Hall Effect System**	**108**
224	Programmable Current Source	148
228A	Programmable Voltage/Current Source	149
230	Programmable Voltage Source	146
236	Source-Measure Unit	84
236-ILC-3	**Interlock Cable, 3m (10 ft.)**	**177**
237	High Voltage Source-Measure Unit	84
237-ALG-2	**Low Noise Triax Cable, 1.2m (4 ft.)**	**177**
237-TRX-T	**3-Slot Male Triax to Dual 3-Lug Female Triax Tee Adapter**	**184**
237-TRX-TBC	**3-Lug Female Triax Bulkhead Connector**	**184**
238	**High Current Source-Measure Unit**	**84**
247	Regulated High Voltage Supply	151
251	**I-V Test Software**	**77**
261	Picoampere Source	152
262	Nanovolt Low Thermal Voltage Divider	72
263	Calibrator/Source	153

400

428	**Current Amplifier**	**64**
480	Digital Picoammeter	62
485	Autoranging Digital Picoammeter	62
486	**Picoammeter**	**60**
487	**Picoammeter/Voltage Source**	**60**

500

500-SERIAL	**RS-232 to IEEE-488 Converter**	**171**
580	Micro-ohmmeter	73
590	C-V Analyzer	96
595	Quasistatic C-V Meter	93

600

602	Solid State Electrometer (battery)	59
610C	Electrometer (bench)	59
614	Digital Electrometer	55
617	Programmable Electrometer/Source	53, 108
617-HIQ	**Programmable Electrometer/Source**	**53**
642	Digital Electrometer	57
642 LNFPA	Digital Electrometer	57

700

705	20-Channel Scanner Mainframe	112
705/7065	Hall Effect Card/Scanner	102
706	100-Channel Scanner Mainframe	112
707	Switching Matrix Mainframe	114
740	System Scanning Thermometer	43
775A	Programmable Counter/Timer	45

900

925A	Room Temperature Hall System	104
925B	Dual Temperature Hall System	104
926A	Room Temperature Differential Hall Profiler	104
926B	Dual Temperature Differential Hall Profiler	104

1000

1010	Single Rack Mounting Kit	200
1017	Dual Rack Mounting Kit	200
1019A-1	Single Fixed Rack Mounting Kit	200
1019A-2	Dual Fixed Rack Mounting Kit	200
1019S-1	Single Slide Rack Mounting Kit	201
1019S-2	Dual Slide Rack Mounting Kit	201
1301	Temperature Probe	172
1481	Low Thermal Input Cable with Clips, 1.2m (4 ft.)	177
1482	Low Thermal Input Cable with Unterminated Leads, 3m (10 ft.)	177
1483	Low Thermal Connection Kit	184
1484	Refill Kit for 1483 Kit	184
1485	Female Low Thermal Input Connector	184
1486	Male Low Thermal Input Connector	184
1488	Low Thermal Shorting Plug	184
1489	Replacement Battery Pack for 148	199
1506	Low Thermal Input Cable, 1.2m (4'), Clips	177
1507	Low Thermal Input Cable, 1.2m (4'), Lugs	177
1600A	High Voltage Probe	172
1651	50-Ampere Shunt	172
1681	Clip-On Test Lead Set	172
1682A	RF Probe	173
1683	Universal Test Lead Kit	173
1684	Hard Shell Carrying Case for Bench DMMs	204
1685	Clamp-On Current Probe	173
1686	Vinyl Carrying Case	204
1691	General Purpose Test Leads	173
1699	Spare Parts Kit for 169	196
1751	Safety Test Leads	173
1753A	IEEE-488 Interface for 175A	165
1754	Safety Universal Test Lead Kit	173
1755	Calibration Interface	196
1758	Rechargeable Battery Pack for 175A, 485	199
1759	Spare Parts Kit for 175A	196
1766	Battery Eliminator for 169	199
1779	Spare Parts Kit for 177	196
1788	Rechargeable Battery Pack for 177, 179A, 480	199
1792	Isolated BCD Output for 177, 179A, 480	165
1793	Isolated IEEE-488 Output for 177, 179A, 480	165
1815	Maintenance Kit for 181	196
1930	TRMS AC-V Option for 193A	164
1931	Current Option for 193A	164
1938	Fixed Rack Mounting Kit for 193A, 194A, 236, 237, 238	201
1939	Slide Rack Mounting Kit for 193A, 194A, 236, 237, 238	201
1942	External Sample Trigger Cable	177
1944A	Second Channel for 194A	164
1950	DCA, TRMS ACV and ACA Option for 195A	164
1951	Platinum RTD Adapter for 195A	185
1972A	IEEE-488 Interface with Analog Output for 197A	165
1973A	IEEE-488 Interface for 197A	165
1978	Rechargeable Battery Pack for 197A, 580	199
1979	Spare Parts Kit for 197A	197
1992	8-Channel Scanner Option for 199	164
1993	Quick Disconnect Scanner Connector Kit for 1992	185
1998-1	Single Fixed Rack Mount Kit for 199	201
1998-2	Dual Fixed Rack Mount Kit for 199	201

2000

2000	Single Rack Mounting Kit for 427 and 642	201
2243	IEEE-488 Interface for 224	166
2286	Safety Output Assembly for 228A	185
2288	Fixed Rack Mounting Kit for 228A	201
2289A	Slide Rack Mounting Kit for 228A	202
2361	Trigger Control Unit	82
2503	Static Detector Probe	174

3000

3321	**LCZ Meter**	**155**
3322	**LCZ Meter**	**155**
3323	**Test Fixture**	**192**
3324	**4-Terminal Alligator Clip Test Leads**	**174**
3325	**Kelvin Clip Test Leads**	**174**
3326	**Chip Component Test Leads**	**174**
3900-1	**Single Fixed Rack Mount Kit**	**202**
3900-2	**Dual Fixed Rack Mount Kit**	**202**
3910	**Function Synthesizer**	**158**
3913	**IEEE-488 Interface for 3910**	**166**
3930A	**Function Synthesizer**	**158**
3933A	**Phase Shifter**	**159**
3940	**Function Synthesizer**	**158**
3949	**Interconnect Cable**	**178**

4000

4003A	Single Rack Mounting Kit for 261	202
4288-1	**Single Fixed Rack Mount Kit for 428, 486, 487**	**202**
4288-2	**Dual Fixed Rack Mount Kit for 428, 486, 487**	**202**
4801	Low Noise BNC Input Cable, 1.2m (4 ft.)	178
4802-10	Low Noise BNC Input Cable, 3m (10 ft.), unterminated	178
4803	Low Noise Cable Kit	178
4804	Male BNC to Female Triax Adapter	185
4851	BNC Shorting Plug	185
4853	IEEE-488 Interface for 485	166

5000

5801	Test Lead Pouch	204
5802	Isolated Analog Output/IEEE-488 Interface	166
5804	General Purpose, 4 Terminal Test Lead Set	174
5805	Kelvin Probes, 0.9m (3 ft.)	174
5805-12	Kelvin Probes, 3.6m (12 ft.)	174
5806	Kelvin Clip Leads	174
5807-7	Helical Spring Point Test Leads, 2.1m (7 ft.)	175
5904	20nF/20mS Adapter	185
5905	Calibration Sources for 590/1M	100, 197
5906	Calibration Sources for 590/100k/1M/4	100, 197
5907	Cable/Matrix Calibration Sources	100, 197
5909	Model 82 Calibration Sources	100, 197
5951	Remote Input Coupler for Model 82	185
5955	Calibration Capacitor Set for 595	100, 197
5956	C-V Software for Model 82 on HP Computers	89
5957-DOS	C-V Software for Model 82 on DOS computers	89
5957-PS/2	**C-V Software for Model 82 on DOS computers**	**89**
5958	**C-V Software Utilities**	**91**

6000

6011	Input Leads, 1.5m (5 ft.), Triax to Clips	178
6011-10	Input Leads, 3m (10 ft.), Triax to Clips	178
6012	Triax to UHF Adapter	185
6101A	Shielded Probe	175
6103C	Voltage Divider Probe (1000:1)	175
6105	Resistivity Chamber	192
6146	Triax Tee Adapter	186
6147	Male Triax to Female BNC Adapter	186
6167	Guarded Input Adapter for 220, 224, 602, 614	186
6171	3-Slot Male to 2-Lug Female Triaxial Adapter	186
6172	2-Slot Male to 3-Lug Female Triaxial Adapter	186

Index Numerical

New products are listed in bold.

6176 Adapter Kit ... 186
6421 Desiccant Paper Refill ... 198
6422 Isolated BCD Output for 642 ... 166
6423 Isolated IEEE-488 Output for 642 ... 166
6424 BNC Input Adapter for 642 ... 186
6425 GenRad GR874® Air Line Input Adapter for 642 ... 186
6426 Sapphire Insulated Test Box ... 192
6427-20 Interconnect Cable for 642, 6m (20 ft.) ... 178
6427-50 Interconnect Cable with Remote Supply for 642, 15m (50 ft.) ... 178
6428 Battery Adapter for 642 ... 199

7000

7007-1 Shielded IEEE-488 Cable, 1m (3.2 ft.) ... 178
7007-2 Shielded IEEE-488 Cable, 2m (6.5 ft.) ... 178
7008-3 IEEE-488 Digital Cable, 0.9m (3 ft.) ... 179
7008-6 IEEE-488 Digital Cable, 1.2m (6 ft.) ... 179
7010 Shielded IEEE-488 to IEEE-488 Adapter ... 187
7023 Female Triaxial Bulkhead Connector ... 187
7024-3 Triaxial Cable, 0.9m (3 ft.) ... 179
7024-10 Triaxial Cable, 3m (10 ft.) ... 179
7025-10 Low Noise Triaxial Input Cable, 3m (10 ft.), one end unterminated ... 179
7051-2 BNC Interconnect Cable, 0.6m (2 ft.) ... 179
7051-5 BNC Interconnect Cable, 1.5m (5 ft.) ... 179
7051-10 BNC Interconnect Cable, 3m (10 ft.) ... 179
7052 5×4 Matrix Switching Card ... 118
7053 High Current Switching Card ... 118
7054 High Voltage Switching Card ... 119
7056 General Purpose Relay Switching Card ... 119
7057A Thermocouple Switching Card ... 120
7058 Low Current Switching Card ... 120
7059 Low Voltage Switching Card ... 121
7061 Universal Adapter Card ... 121
7062 RF Switching Card (50Ω, unterminated) ... 122
7063 RF Switching Card (50Ω, terminated) ... 122
7064 20-Channel Low Voltage Switching Card ... 122
7065 Hall Effect Card ... 102
7066 Universal Adapter Card ... 123
7067 Four-Wire Scanner Card ... 123
7068 Fixed Rack Mounting Kit for 706 ... 202
7069 Slide Rack Mounting Kit for 706 ... 202
7070 Universal Adapter Card for 707 ... 129
7070-PCA Prototype Circuit Assembly ... 129
7071 8×12, General Purpose Matrix Card for 707 ... 130
7071-4 Dual 4×12, General Purpose Matrix Card for 707 ... 131
7072 8×12, Semiconductor Matrix Card for 707 ... 132
7072-HV 8×12, High Voltage Semiconductor Matrix Card for 707 ... 133
7073 8×12, Coaxial Matrix Card for 707 ... 134
7074-CIT Contact Extraction Tool for 7074-KIT, 7074-MTR ... 187
7074-D Eight 1×12 General Purpose Multiplexer (Dry Reed) ... 135
7074-HCT Hand Crimping Tool for 7074-KIT, 7074-MTR ... 187
7074-KIT 75-Pin Mass Terminated Plug with Contacts ... 187
7074-M Eight 1×12 General Purpose Multiplexer (Mercury Wetted) ... 135
7074-MTC-20 Mass Terminated Cable Assembly, 6m (20 ft.) ... 179
7074-MTR 75-Pin Mass Terminated Receptacle ... 187
7074-RTC Relay Test Shorting Connector for 7074 ... 187
7075 Eight 1×12, 2-Pole Multiplexer Card for 707 ... 136
7075-MTC Row, Column, or Bank Cable Assembly for 7075 and 7076, 3m (10 ft.) ... 179
7076 Dual 4×12, 2-Pole Matrix Card for 707 ... 137
7076-CMTC High Isolation Column or Bank Cable Assembly for 7075 & 7076, 3m (10 ft.) ... 180
7076-RMTC High Isolation Row Cable Assembly for 7075 & 7076, 3m (10 ft.) ... 179
7078-CIT Contact Insertion/Extraction Tool for 7078-, 7152-, and 7169-KIT and -MTR ... 187
7078-CSHP Cable Set to Connect 7072 to HP-4145B ... 180
7078-DIN 8-Pin DIN Cable, (Master/Slave) for 707 ... 180
7078-HCT Hand Crimping Tool for 7078-KIT, 7169-KIT ... 187
7078-KIT Connector Kit ... 188
7078-MTC-5 Mass Terminated Cable Assembly, 1.5m (5 ft.) ... 180
7078-MTC-20 Mass Terminated Cable Assembly, 6m (20 ft.) ... 180
7078-MTR Mass Terminated Receptacle, Bulkhead Mount ... 188
7078-PEN Programming Light Pen for 707 ... 198
7078-TRX-3 3-Slot Low Noise Triax Cable, 0.9m (3 ft.) ... 180
7078-TRX-10 3-Slot Low Noise Triax Cable, 3m (10 ft.) ... 180
7078-TRX-20 3-Slot Low Noise Triax Cable, 6m (20 ft.) ... 180
7078-TRX-BNC 3-Lug Triax to BNC Adapter ... 188
7078-TRX-GND 3-Lug Triax to BNC Adapter (guard removed) ... 188
7078-TRX-T 3-Lug Triax Tee Adapter ... 188
7078-TRX-TBC 3-Lug Female Triax Bulkhead Connector ... 188
7079 Slide Rack Mount for 707 ... 203
7152 4×5 Low Current Matrix Card ... 124
7152-HCT Hand Crimp Tool for 7152-KIT, 7152-MTR ... 188
7152-KIT 6-Position M-Series Plug w/Contacts ... 188
7152-MTC-2 Low Noise Matrix Expansion Cable, 0.6m (2 ft.) ... 180
7152-MTC-10 Low Noise Matrix Expansion Cable, 3m (10 ft.) ... 180
7152-MTR 6-Position M-Series Receptacle w/Sockets ... 189
7152-TRX-10 Low Noise M-Series to Triax Cable, 3m (10 ft.) ... 180
7153 4×5 High Voltage Low Current Matrix Card ... 124
7153-TRX Low Noise M-Series to Triax Cable, 1.5m (5 ft.) ... 181
7154 High Voltage Scanner Card ... 125
7156-D 1×10 General Purpose Multiplex Card (Dry Reed) ... 125
7156-KIT 37-Pin Mass Terminated Connector ... 189
7156-M 1×10 Gen. Purpose MUX Card (Mercury Wetted) ... 125
7156-MTC-10 Mass Terminated Cable Assembly, 3m (10 ft.) ... 181
7156-MTR Mass Terminated Bulkhead Mount Receptacle ... 189
7158 Low Current Card ... 126
7164-D 20-Channel Scanner Card (Dry Reed) ... 126
7164-KIT 50-Pin Mass Terminated Connector ... 189
7164-M 20-Channel Scanner Card (Mercury Wetted) 126
7164-MTC-10 Mass Term. Cable Ass'y for 7164, 3m (10 ft.) ... 181
7164-MTR 50-Pin Mass Term. Bulkhead Mount Receptacle ... 189
7166 Mercury Relay Scanner Card ... 127
7168 Nanovolt Scanner Card ... 127
7169 20 Form C Switch Card ... 128
7169-KIT 20-Pin Mass Terminated Connector ... 189
7169-MTC-3 Mass Terminated Cable Assembly, 3m (10 ft.) ... 181
7169-MTR Mass Terminated Bulkhead Mount Receptacle ... 189
7401 Thermocouple Wire Kit, 30m (100 ft.), Type K ... 181
7402 Thermocouple Scanner Card ... 120
7754-3 BNC to Alligator Cable, 0.9m (3 ft.) ... 181
7755 50Ω Feed-Through Terminator ... 189

8000

8000 Equipment Cabinet, 28 in. high ... 203
8000-10 Equipment Cabinet, 10 in. high ... 203
8000-14 Equipment Cabinet, 14 in. high ... 203
8002A High Resistance Test Box with Cables ... 193
8003 Low Resistance Test Box with Cables ... 193
8006 Component Test Fixture ... 194
8006-CTM Component Test Module for 8006 ... 194
8006-MJC Red/Black Teflon Clip Jumpers ... 181
8006-MJG Guarded Teflon Mini Jumpers (8) ... 181
8006-MJS-1 Red Teflon Mini Jumpers (10) ... 181
8006-MJS-2 Black Teflon Mini Jumpers (10) ... 181
8006-MJS-3 Blue Teflon Mini Jumpers (10) ... 181
8007 Semiconductor Test Fixture ... 195
8007-GND-3 Safety Ground Wire ... 182
8007-MTC-3 Mass Terminated Cable Assembly, 3m (10 ft.) ... 182
8007-PTB Prototype Board ... 195
8008 Resistivity Test Chamber ... 193
8008-BAN Interface Cables (banana plugs) ... 182
8691 Pt RTD Connector Adapter Kit for 195A ... 189
8693 Pt RTD General Purpose Probe for 195A ... 175
8695 Pt RTD Surface Probe for 195A ... 175
8696 Pt RTD Air/Gas Probe for 195A ... 175

19072 Coaxial Input Cable ... 182
25790 Vented Rack Panel ... 203
32418 UHF-MHV Cable ... 182

CA-18-1 Shielded Cable (dual banana plug), 1.2m (4 ft.) ... 182
CS-115 UHF-BNC Adapter ... 189
CS-141 2-Slot Male Triax Connector ... 189
CS-631 3-Slot Male Triax Connector ... 189

GP488B IEEE-488 Interface Card ... 171

PC-488-CEC IEEE-488 Interface Card for IBM PC/XT/AT ... 169
PC-488-COP Co-Operator™ Software; Interactive Programming Aid w/PC-488-CEC ... 170
PC-488-GRAPH Graphics Software for IBM PC/XT/AT ... 170
PC-488-INT BASIC Interrupt Handling Software with PC-488-CEC for IBM PC/XT/AT . 170
PS-488-CEC IEEE-488 Interface Card for IBM PS/2 ... 169
PS-488-COP Co-Operator™ Software; Interactive Programming Aid w/PS-488-CEC ... 170
PS-488-GRAPH Graphics Software for IBM PS/2 ... 170
PS-488-INT BASIC Interrupt Handling Software with PS-488-CEC for IBM PS/2 ... 170

SC-9 Coax Cable (unterminated) ... 182
SC-22 Triax Cable (unterminated) ... 182

Upgrade Chart

The following is a list of older Keithley products and suggested replacement models which can be used to upgrade the capabilities of these older products. To ensure adequate replacement, please review the replacement instrument's specifications in this catalog. If the suggested replacement does not meet specific application requirements or if the model being upgraded is not listed, contact the Keithley Applications Department or your local Keithley representative for assistance.

OLDER MODELS	DESCRIPTION	SUGGESTED UPGRADES	PAGE
ELECTROMETERS			
200, 200A, 200B, 210, 220	Electrometer Voltmeters	602, 614	59, 55
600, 600A, 600B, 620, 621	Analog Electrometers (battery operated)	602, 614	59, 55
610, 610A, 610B, 610BR, 610R	Electrometers	236, 487, 610C, 617	84, 60, 59, 53
615, 616	Digital Electrometers	236, 487, 617	84, 60, 53
603, 604, 619	Dual Electrometers	236, 486, 617	84, 60, 53
640	10^{17}A Electrometer	642	57
PICOAMMETERS			
409, 410, 410A, 411, 414, 414A, 414S, 415	Picoammeters	480, 485, 486, 487, 614	62, 60, 55
412, 413, 26000	Log Picoammeters	485	62
418, 419, 440, 445, 619	Digital Picoammeters	486, 487	60
416, 417, 427	High Speed Picoammeters	428 with 196, 486, 487	64, 60
LOW VOLTAGE INSTRUMENTS			
140, 147, 148, 149, 150, 181	Nanovoltmeters/	182	68
150A, 150B, 180, 181, 303	Null Detectors	155, 182	71, 68
151, 151C, 153	Microvoltmeters/ Null Detectors	155, 182	71, 68
DIGITAL MULTIMETERS			
160, 160B, 161, 163, 171	DMMs (1μV)	177, 197A, 199	41, 30, 24
165, 167, 168	DMMs (low-cost)	169, 175A	42, 39
174, 175, 192, 197	DMMs (100nV)	182, 196	68, 27
190, 191, 195, 195A, 195T	DMMs (5½ digits)	199	24
172, 172A, 173, 176, 178, 179, 179-20A	DMMs (4½ digits) (10μV)	175A, 179A	39, 41
5900, 6900, 192, 193	System DMMs	193A, 199, 196	34, 24, 27
DIFFERENTIAL VOLTMETERS			
660, 660A, 661, 662, 630	Differential Voltmeters	193A, 195A, 196, 197A, 199	34, 32, 27, 30, 24
RESISTANCE MEASURING INSTRUMENTS			
502, 502A, 505, 164	Milliohmmeters	580	73
500, 501, 510, 515, 520	High-Resistance Instruments	617, 263, 487	53, 153, 60
CURRENT SOURCES			
225	Current Source	220, 236	146, 84
261	Current Source	263	153
227, 228	Current Source	228A, 238	149
VOLTAGE SOURCES			
240, 240A, 241, 242, 243, 244, 245, 246, 2004, 2004A	High Voltage Supplies	247, 237	151, 84
260	Nanovolt Source	262	72
SWITCHES			
702	Scanner	705	112
703	Scanner	706	112
SPECIAL PURPOSE ACCESSORIES			
250	Static Meter	610C with 2503	59
1641	Kelvin Clips	5806	174
8573, 8573A	IEEE-488 Interface Card	PC-488-CEC	168

Technical Literature

The following literature is available at no charge by marking your request on the reply card in the back of this catalog, or by calling **1-800-552-1115.**

TECHNICAL DATA SHEETS

- Model 82 C-V System
- Model 175 DMM
- Model 175-AV DMM
- Model 177 DMM
- Model 181 Nanovoltmeter
- Model 193A DMM
- Model 194 Technical Supplement
- Model 196 System DMM
- Model 197 DMM
- Model 213 Quad Voltage Source
- Model 220/230 Current/Voltage Sources
- Model 224 Current Source
- Model 228A Voltage/Current Source
- Model 262 Voltage Divider
- Model 263 Calibrator/Source
- Model 480 Picoammeter
- Model 485 Picoammeter
- Model 580 Micro-ohmmeter
- Model 617 Electrometer/Source
- Model 617-HIQ Electrometer/Source
- Model 619 Electrometer
- Model 642 Electrometer
- Model 1755 Calibration Interface
- Model 2361 Trigger Controller
- Model 7065 Hall Effect Card

PRODUCT BROCHURES

- Model 82 C-V System Demo Guide
- Model 175A/197A DMM Brochure
- Model 182 Sensitive Digital Voltmeter Brochure
- Model 194A High Resolution Digitizer Brochure
- Model 236/7 SMU Application Booklet
- Model 236/7/8 SMU Brochure
- Model 236/7 SMU Tutorial
- Model 251 I-V Test Software Brochure
- Model 428 Current Amplifier Brochure
- Model 428/486/487 Applications Booklet
- Model 485 Picoammeter Brochure
- Model 486/487 Picoammeters Brochure
- Model 580 Micro-ohmmeter Brochure
- Model 580 Micro-ohmmeter Case History
- Model 617 Electrometer/Source Brochure
- Model 705 Scanner Brochure
- Model 707 Switching Matrix Brochure
- Model 707 Switching Matrix Configuration Guide
- Model 740 System Thermometer Brochure
- Model 775A Counter/Timer Brochure
- C-V Brochure
- C-V Folder
- Customer Service Brochure
- DMM Brochure
- Hall Effect Measurements Brochure
- Semiconductor Measurements Brochure
- SMU Folder
- Sources Brochure
- Superconductivity Measurements Brochure
- Switching Cards & Accessories Brochure
- Switching Folder
- Test Fixtures Brochure

APPLICATION NOTES

- **100:** *Low Current Measurements,* R. Erdman.
- **120:** *Capacitor Leakage Measurements,* J. Yeager.
- **130:** *Uranium Systems Calibration for the Keithley Model 642 Electrometer,* J. C. Banar, R. E. Perrin, & C. M. Miller.
- **200:** *Understanding Low Voltage Measurements,* R. Erdman.
- **290:** *Static Charge Measurements,* J. Yeager.
- **301:** *Automating Low Resistance Measurements,* K. Rosenow.
- **302:** *Insulation Resistance Testing of Printed Circuit Boards,* M. A. Hrusch.
- **311:** *Automating High Resistance Measurements,* K. Rosenow.
- **401:** *Specifying Temperature Measuring Systems,* G. Erb.
- **610:** *Designing Software Using State Table Driven Code,* P. D'Angelo.
- **700:** *Switching In Multipoint Testing,* P. Bowen.
- **801:** *Trigger Capability of Soft500,* E. Ewan.
- **802:** *Low DC Voltage Measurements in the Calibration Lab,* D.R. Workman.
- **803:** *Formatting Instrumentation Data for Lotus 1-2-3, ASYST, and DADiSP II,* J. Rochow.
- **804:** *Comparing Data Acquisition Software for PCs,* B. Radcliffe.
- **805:** *Choosing PC-Based Data Acquisition Hardware,* S. Lekas.
- **806:** *Using a Personal Computer for Laboratory Recording,* T. LaSalvia.
- **807:** *Titration,* T. LaSalvia.
- **808:** *Utilizing IEEE-488 Translator Software,* P. D'Angelo.
- **809:** *Combining Data Acquisition and GPIB Control,* K. Hutchison.
- **810:** *PC-Based Replacement of the Laboratory Oscillograph,* G. Zumpetta.
- **811:** *Simplifying Resistor Temperature Coefficient Test System Using Model 196,* D. Kocher
- **812:** *Using a PC-Based Data Acquisition System to Emulate an X-Y Plotter,* T. LaSalvia.
- **813:** *Attaining High Rates of Real Time Data Acquisition and Transfer,* M. Welo.
- **814:** *PC-488-CEC IEEE Interface,* P. Bowen.
- **815:** *Graphics and Analysis of Soft500 Data Using Lotus 1-2-3 and DADiSP II,* G. Zumpetta.
- **816:** *New Keithley Hardware Mates Data Acquisition to More PC Compatibles and Personal System/2,* G. Zumpetta.
- **817:** *Obtaining Maximum Sensitivity and Resolution with Your Model 196 System DMM,* B. Green.
- **818:** *Producing Chart-Recorder Style Hardcopy with a PC and a Graphic Printer,* G. Zumpetta.
- **819:** *Controlling Stepper Motors with an IBM PC/AT or Compatible Computer,* H. Horn.
- **820:** *Impact of Signal Switching on Critical Test Requirements of Automatic Test Systems,* J. Yeager.
- Model 580 Application Examples
- Application Note Index

LAB NOTES

- Superconductivity
- Bias Temperature Stress (BTS)
- 236 I-V Characterization
- Electrical Experiments Series I and II
- Physics Experiments Series I and II

ARTICLE REPRINTS

- "Accurate Automated Measurement of Superconductor Material Resistance", *Research & Development,* 6/88
- "Measuring Low Contact Resistance Values", *Connection Technology,* 6/87
- "Signal Switching in Automated Test Equipment", *Machine Design,* 12/88
- "DVM/DMM Applications", *Evaluation Engineering,* 8/88
- "Thermal Effects in High-Resolution DMMs", *Test & Measurement World,* 8/88
- "Using Simultaneous Feedback-Charge Quasistatic and High-Frequency C-V for Better C-V Data in Half the Time", *Microelectronic Manufacturing & Testing,* 7/88
- "Switching Systems Speed Test and Add Flexibility", *Electronic Test,* 5/89
- "Excited Dyes Improve Photosensitivity of Semiconductors", *Research & Development,* 6/89
- "Effective Switching Reduces Test Errors", *Electronic Test,* 8/89
- "Matrix Switches Remain a Test-System Mainstay", *Electronic Design,* 8/89
- "Advances in Instrumentation for C-V Measurement", *Solid State Technology,* 8/89
- "Temperature Measuring Techniques", *Test & Measurement World,* 9/89
- "New System Makes It Easy to Profile Soft Vacuum Beams", *Research & Development,* 2/90
- "MOS and CMOS as Drivers of C-V Technology", *Solid State Technology,* 3/90
- "SMUs Offer Significant Measurement Advantages", *Electronic Test,* 4/90
- "The Role of C-V Profiling in Semiconductor Characterization", *Solid State Technology,* 4/90
- "Guidelines for Interpreting C-V Data", *Solid State Technology,* 5/90
- "This Instrument Simplifies Circuit Measurements", *Research & Development,* 5/90

REFERENCE PUBLICATIONS

Switching Handbook

This helpful guide to switching applications describes relay characteristics, switching specifications, selection criteria, system integration hints, and guidelines for optimizing your test system. Developed with years of experience in instrumentation systems, the handbook also includes sample switching applications and programming.

Low Level Measurements Handbook

This book describes theoretical and practical considerations involved in the measurement of low DC currents, high resistances, and low DC voltages. It also discusses design characteristics of electrometers, which are used for both low current and high resistance measurements, as well as for measurements from high resistance voltage sources.

Customer Service

The Right Instruments — The Right People

Keithley instruments and systems are found in universities, industrial research laboratories, engineering development departments, quality control areas, and on production lines throughout the world. This wide acceptance is largely due to the technical support provided by our Applications Department.

A team of dedicated Applications Engineers is available to answer questions or provide other technical assistance. Our team offers customers a combined electronic engineering experience of more than 75 years. Their job is not just to "answer customer questions" but to "solve customer problems." They have the design expertise to advise you on configurations, measurement techniques, and error sources in the most sensitive circuits.

"Troubleshooting" is another major part of the Department's job. We can help you determine whether a measurement problem is the result of an instrument failure or a design glitch in your configuration.

With fax or a modem, an engineer can quickly transmit a suggested system configuration to you. Keithley offers this service free of charge via our toll-free hot line.

Electronics Manufacturing

Component Test

Our programmable sourcing, measurement, and connection instruments combine wide dynamic range with high sensitivity for exceptional accuracy in many component characterization and testing applications.

Sensitive, high-speed electrometers and picoammeters are available for applications such as ensuring capacitor leakage current remains below a specified level. Keithley's programmable DC voltage sources will help achieve precise results in tests that call for "soaking" a capacitor before measuring it.

For high throughput without sacrificing signal integrity, Keithley instruments and switches simplify the configuration of automated component testing systems. For example, to improve design reliability and gain a better understanding of circuit operation, many engineers need to characterize contact and connector potential. A Keithley micro-ohmmeter or sensitive digital voltmeter, combined with a variety of switching products, provides a sensitive, high-speed solution.

The ability to characterize complex impedances over a range of frequencies can simplify the process of improving component design and performance. A Keithley LCZ meter, part of our new line of AC measurement products, can provide more accurate data.

Circuit Assembly Test

Testing circuits and assemblies generally requires a variety of stimulus and measurement instruments. Keithley is the world leader in low-level DC measurements, which are critical in accurately determining attributes such as insulating properties, bias currents, or leakage characteristics.

A wide range of DMMs and nanovoltmeters are available, as well as a sensitive digital voltmeter with 1nV sensitivity and 6½-digit resolution. These highly flexible tools are ideal for tasks like calibrating voltage reference circuits, determining small differential values in a bridge circuit, or circuit verification and testing.

For applications such as measuring power supply and common mode rejection ratios, Keithley's programmable voltage sources and high resolution DMMs simplify the measurement technique without compromising sensitivity or accuracy.

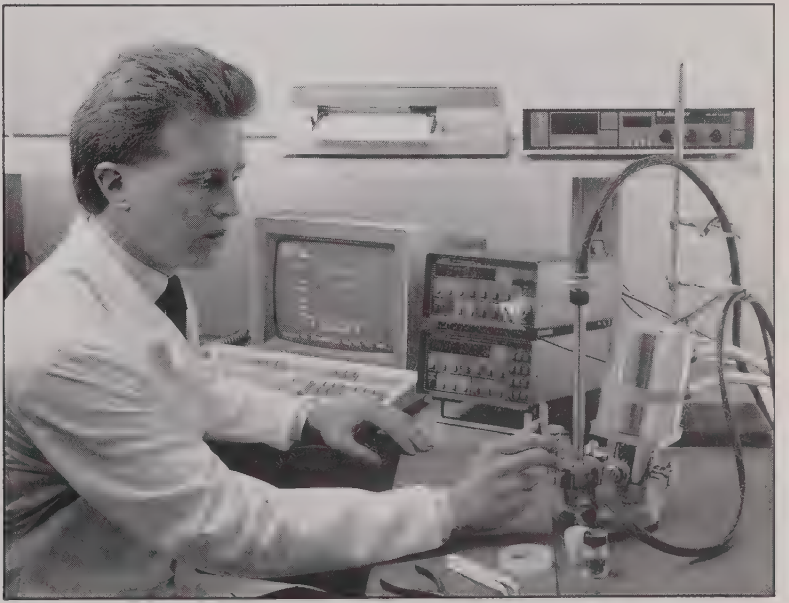
To understand how circuits and subsystems operate, engineers often need to characterize frequency response. Keithley's function synthesizers, part of our new AC measurement products line, are well-suited to such tasks.

Automatic Test Systems

Signal switching is the heart of every automatic test system. Keithley offers the widest variety of programmable switching instruments, all designed to maintain signal integrity throughout the test system. Combining IEEE-488-based instruments with switching products simplifies operation and boosts performance.

Our switching products provide instrumentation-grade switching for precision measurements. Keithley's wide selection of cards allows you to choose one that closely matches your signal requirements. Each switching card is fully specified for electrical performance so you can predict its effect in your system.

Three switching mainframes provide a convenient environment for bench, worksta-



For further information or applications assistance, call the Applications Department toll-free at 1-800-552-1115. The Applications hot line is in operation every business day, from 8:00 A.M. - 7:00 P.M. Eastern Time.

tion, or production test systems. Each is engineered to simplify operation, programming, and verification of test results.

Keithley interface accessories and software for data acquisition, and analysis of test results on personal computers make it easy to integrate system components, speeding test development and improving system performance.

Scientific Research

Reliable data and dependable system performance are critical in scientific research. Keithley offers a wide variety of components and systems for use in low-level voltage and current measurements, Hall Effect measurements, and charge measurements.

For low-level voltage measurements, the high resolution capabilities of our sensitive digital voltmeters and nanovoltmeters lead the field in research into superconductivity, contact potential, and other low voltage applications.

The sensitivity of Keithley's picoammeters and the low interference of our switching products have made them popular choices for low-level current measurements in applications such as electrochemistry, biology, mass spectrometry, and semiconductor characterization.

Keithley's line of Hall Effect measurement products are widely used in research of semiconductors, metals, and insulators. They range from individual instruments to fully-configured turnkey systems and differential profilers, complete with system software.

Precision charge measurements are often critical in research applications such as physics, chemistry, and the characterization of insulators. Keithley offers a multifunction electrometer with charge sensitivity to 10^{-14}C.

Semiconductor Applications

Keithley offers a variety of instruments and systems uniquely suited to the needs of the semiconductor community. Our C-V, I-V, and Hall Effect systems can make the critical difference in the outcome of your research or help keep your production line running.

Semiconductor Characterization

Our line of capacitance voltage measurement equipment is engineered to speed the characterization of important semiconductor parameters such as interface trap density, doping profiles, effective charge, and flat band voltage. For example, by measuring a capacitor's interface trap density before and after exposure to radiation, hot electron stress, or other damage, researchers can gauge the potential effects of this damage to the device. Keithley's simultaneous C-V systems can speed and simplify this process by making quasistatic and high frequency C-V measurements in one voltage sweep without changing connections, reducing the inaccuracies of older techniques.

Electromigration

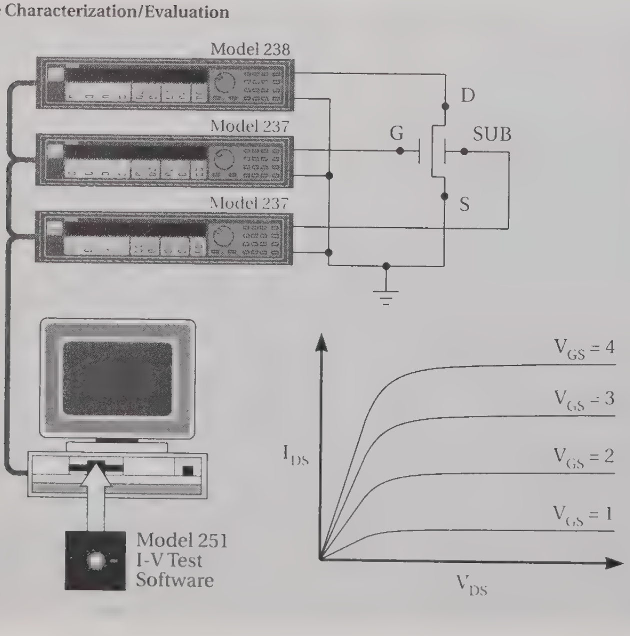
Keithley can supply instruments and switches for both wafer level and packaged device evaluation tests. Our Applications Team can help you configure the optimum combination of source, DMM, and switching.

I-V Characterization

Our semiconductor evaluation instruments and systems can simplify reliability testing, quality control, new process development, and I-V characterization. Keithley Source-Measure Units (SMUs) can simultaneously source voltage and measure current or source current and measure voltage. Each SMU functions as an electrometer, DMM, current source, and voltage source. This replaces several individual instruments and switches, providing better signal integrity, higher reliability, and simpler connections at a lower cost. Virtually any I-V test can be performed by simply connecting one SMU to each pin of the DUT.

The new Model 251 I-V Test Software Package, designed specifically for I-V characterization, offers interactive testing of current vs. voltage for research and development of semiconductor devices, processes and materials, and for component evaluation. (See diagram.) Using a trigger controller and quad voltage source, the software integrates up to six SMUs to measure and display device characteristics such as I-V curve families, breakdown voltage, leakage current, DC or differential gain, and resistance. The software includes a library of 25 standard tests for popular component tests, diode tests, bipolar transistor tests, FET tests, etc.

Device Characterization/Evaluation



Measurements: An Introduction

The measurement aspect of a test system is usually considered the most important, and also the most difficult to implement. It is important to choose a measuring instrument that adds only an insignificant amount of error to the signal from the device under test (DUT). Thus, if noise, drift, and other sources of error which disturb the signal from the DUT are minimized, the system will meet the stated objectives in terms of error, repeatability, accuracy, etc.

For over 40 years, Keithley has been a leader in the electronic measurement industry, providing very sensitive instruments that can measure extremely small changes in current and voltage as well as extremely high resistances. In recent years, we have also become known for providing high-value DMMs and a variety of other test instruments.

Keithley provides a phone-in applications service, staffed by highly trained engineers, to provide you with additional assistance in solving measurement problems and choosing the most appropriate measuring instruments for your needs. Application notes and booklets discussing various measurement examples are also available from Keithley.

TYPES OF MEASURING INSTRUMENTS

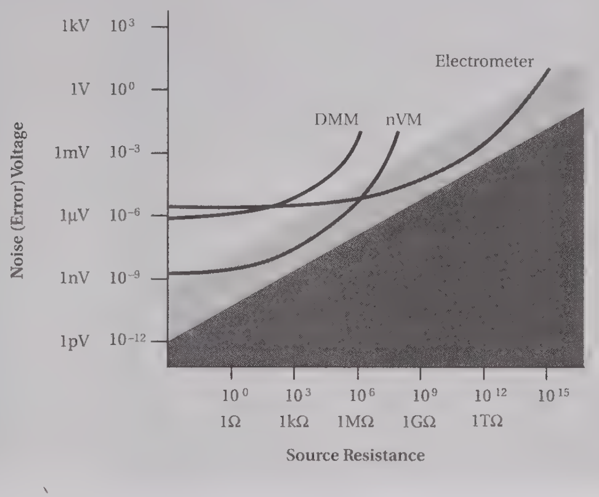
Presented here are guidelines for choosing the right type of measuring instrument. At the front of each of the DMM, electrometer/picoammeter, and nanovoltmeter sections of this catalog are descriptions of measurement considerations related to the type of instrument. Also included are Selector Guides which will help determine the best instrument for your needs.

VOLTS-AMPS-OHMS measurements are most often made using a DMM (Digital Multimeter). A useful guideline is that if a DMM will do your job, it is usually the most cost-effective solution. These instruments are the "workhorses" of most laboratories and test areas. As you can see in the Selector Guide on page 20, a wide variety of accuracy, resolution, speed, and features is available. If the sensitivity (smallest detectable change in voltage, current, or resistance) required is better than a few hundred nV, pA, or μΩ, the more specialized instruments described below are needed.

Nanovoltmeters are voltage-measuring instruments that are more sensitive than DMMs, as shown in **Figure 1**. For example, the Model 182 Sensitive Digital Voltmeter (page 68) is at least a decade more sensitive than DMMs. Standard deviations between sets of averaged readings can be as low as a few nanovolts.

With the Model 7168 Nanovolt Scanner Card (page 127), it is possible to automatically switch between signals at the nanovolt level. This card is the most sensitive nanovolt switch available.

FIGURE 1: Typical Digital Multimeter (DMM), Nanovoltmeter (nVM), and Electrometer Limits of Measurement at Various Source Resistances



Electrometers are DC multimeters with very high input resistance (up to 10^{16} ohms) and very low input current (down to 10^{-17} amperes). As **Figure 1** shows, at high source resistances, an electrometer is far superior to either a DMM or a nanovoltmeter, due to its low input current. In addition to DC voltage and current capabilities, electrometers also measure charge and resistance.

Picoammeters are used in situations where only current is to be measured. While they are lower in cost than electrometers, they are not as sensitive, but they still have much better current sensitivity than a DMM. Both electrometers and picoammeters have much lower input voltage burden than DMMs.

Source-Measure Units (SMUs) combine four instruments (DMM, voltage source, current source, and electrometer) in one stand-alone enclosure. The integration of these instruments provides better speed, sensitivity, and accuracy when sourcing voltage and measuring current, or sourcing current and measuring voltage.

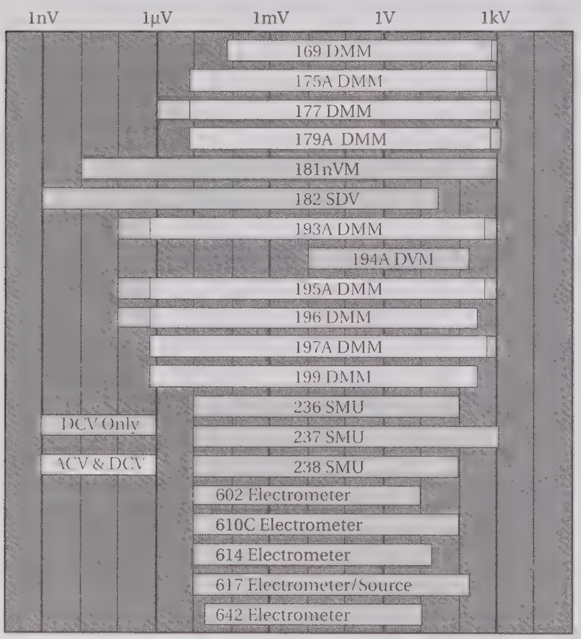
A **Micro-ohmmeter** is needed to measure milliohm level resistances with precision. The Model 580 (page 73) provides a choice of waveforms, provisions for clamping the voltage to industry standard maximum levels, many DMM features, and a variety of test leads, minimizing the effort required to make such sensitive measurements.

Keithley also manufactures sensitive test instrumentation for Hall Effect, C-V (capacitance vs. voltage), temperature, frequency and AC measurements.

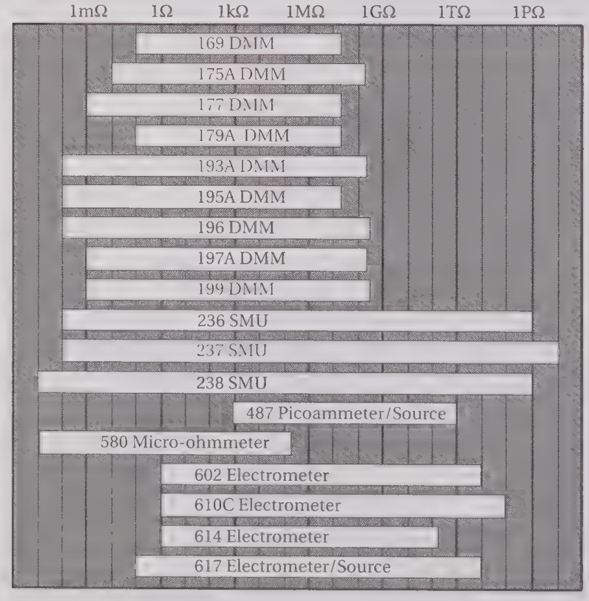
For more information, application assistance, or a demonstration of Keithley's problem-solving instruments, contact your local sales engineer or Keithley Instruments office.

Keithley's Range of Measurements

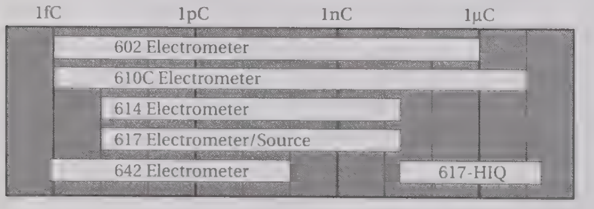
VOLTS



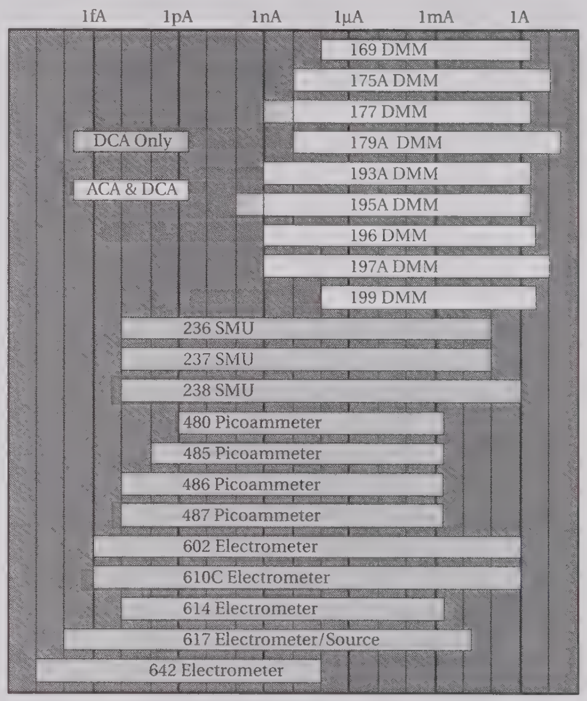
OHMS



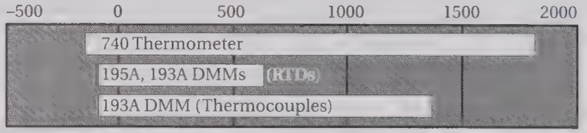
COULOMBS



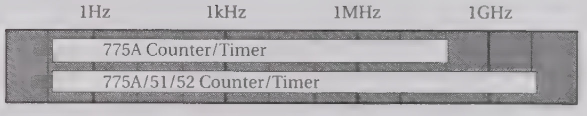
AMPS



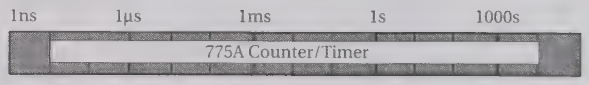
TEMPERATURE (°C)



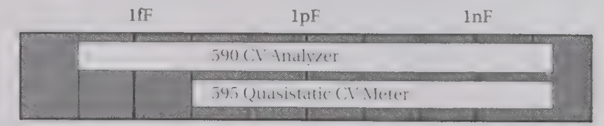
FREQUENCY



PERIOD



SEMICONDUCTOR CAPACITANCE



General Measurements

DIGITAL MULTIMETERS

DMM Selector Guide 20

DMM Technical Data 22

199
5½-Digit DMM 24

199/1992
5½-Digit DMM/Scanner 26

196
6½-Digit DMM 27

197A
5½-Digit Microvolt DMM 30

195A
5½-Digit DMM 32

193A
6½-Digit DMM 34

194A
High Resolution Digitizer 36

175A
4½-Digit Autoranging DMM 39

179A
4½-Digit TRMS DMM 41

177
4½-Digit Microvolt DMM 41

169
3½-Digit Portable/Bench DMM 42

TEMPERATURE MEASUREMENT

740
System Thermometer 43

FREQUENCY MEASUREMENT

775A
Counter/Timer 45

DMMs Selector Guide

MODEL	199	196	197A	195A	193A
Page	24	27	30	32	34
Maximum Display	302 999	3 029 999	219 999	199 999	2 199 999
Digits	4½ to 5½	3½ to 6½	5½	3½ to 5½	3½ to 6½
Display	LED	LED	Bright LCD	LED	LED
DC VOLTS					
Sensitivity	1 µV	100 nV	1 µV	100 nV	100 nV
Maximum Reading	300 V	300 V	1000 V	1000 V	1000 V
Basic Accuracy	0.006%	0.003%	0.011%	0.025%	0.003%
AC VOLTS				(Option)	(Option)
Method	TRMS	TRMS	TRMS	TRMS	TRMS
Sensitivity	1 µV	1 µV	1 µV	1 µV	1 µV
Maximum Reading	300 V	300 V	750 V	700 V	700 V
Basic Accuracy	0.15%	0.15%	0.35%	0.3%	0.25%
OHMS					
Special Features	Auto 2/4 terminal	Auto 2/4 terminal	Auto 2/4 terminal. Diode test.	Auto 2/4 terminal	Auto 2/4 terminal
Sensitivity	1 mΩ	100 µΩ	1 mΩ	100 µΩ	100 µΩ
Maximum Reading	300 MΩ	300 MΩ	220 MΩ	20 MΩ	220 MΩ
Basic Accuracy	0.008%	0.005%	0.018%	0.025%	0.005%
DC AMPS				(Option)	(Option)
Sensitivity	100 nA	1 nA	1 nA	100 pA	1 nA
Maximum Reading	3 A	3 A	10 A	2 A	2 A
Basic Accuracy	0.05%	0.05%	0.1%	0.09%	0.09%
AC AMPS				(Option)	(Option)
Method	TRMS	TRMS	TRMS	TRMS	TRMS
Sensitivity	100 nA	1 nA	1 nA	1 nA	1 nA
Maximum Reading	3 A	3 A	10 A	2 A	2 A
Basic Accuracy	0.6%	0.6%	0.8%	0.6%	0.6%
IEEE-488 INTERFACE					
Configuration	Included	Included	Option	Included	Included
Programmable Parameters	All functions and features	All functions and features	Range (V, Ω), dB, memory, cal, relative reference	All functions and features	All functions and features
Digital Calibration	Front panel or bus	Front panel or bus	Front panel or bus (w/IEEE option)	Front panel or bus	Front panel or bus
Ranging	Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual
Inputs	Front/Rear	Front/Rear	Front	Front/Rear	Front/Rear
Battery Operation	—	—	Optional 5-7 hour	—	—
Special Features	8-channel scanner option: 2-, 4-pole switching, 40 ch./s. 500-rdg. memory, 150 rdg./s. Ratio measurements.	1000 rdg./s. 500-point data logger over bus. Non-volatile TRANSLATOR. Offset compensated ohms. Front panel programs.	Analog + IEEE-488 output option. 100-point data logger. dB mode. Relative reference.	100-point data logger. RTD temperature. Front panel messages. Pushbutton zero.	500-point data logger. RTD & TC temperature. 1000 rdg./s. Non-volatile TRANSLATOR. Low freq. TRMS AC. dB.

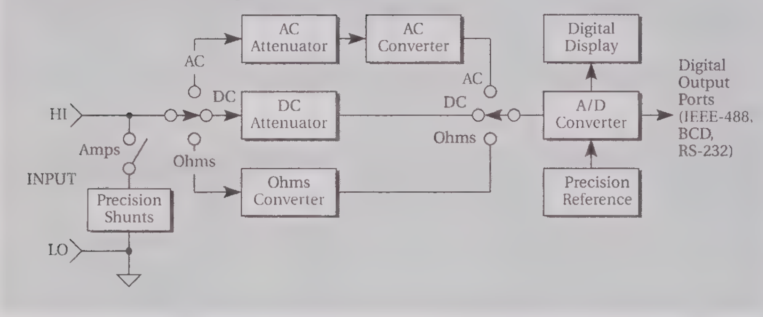
Selector Guide

194A	175A	179A	177	169	182
36	39	41	41	42	68
32 000	19 999	19 999	19 999	1 999	
4½	4½	4½	4½	3½	6½
LED	Bright LCD	LED	LED	LCD	VFD
10 mV	10 μV	10 μV	1 μV	100 μV	1nV
200 V	1000 V	1200 V	1200 V	1000 V	—
0.03%	0.03%	0.04%	0.03%	0.25%	0.005%
• Waveform acquisition • Waveform analysis • Simple system integration **Product Features:** • High speed programmable sampling: 16 bit resolution up to 100kHz 8 bit resolution 100kHz to 1MHz • 2 independent and isolated measurement channels (2nd channel optional) • 64k bytes data memory per channel (90k bytes per second transfer rate over IEEE-488 bus) • External sample strobe rate to 1M/second	TRMS	TRMS	TRMS	Average	• Sensitive digital voltmeter • Dual line display indicates reading, status, menu information • Alternative for low voltage measurements **Product Features:** • 15μV p-p noise • Accuracy to 13ppm of reading + 3ppm of range • Buffer memory capable of storing up to 1024 readings • Min, Max, Average, and Standard Deviation statistical functions • Low thermal input cable and connector minimize thermal offsets
	10 μV	10 μV	10 μV	100 μV	
	750 V	1000 V	1000 V	1000 V	
	0.5%	0.5%	0.5%	0.75%	
	Diode test	HI-LO selectable	Front panel lead compensation	Diode test on 20kΩ range	
	10 mΩ	100 mΩ	1 mΩ	100 mΩ	
	200 MΩ	20 MΩ	20 MΩ	20 MΩ	
	0.05%	0.04%	0.04%	0.2%	
	10 nA	10 nA	1 nA	100 nA	
	10A	20A	2A	2A	
	0.15%	0.2%	0.2%	0.75%	
	TRMS	TRMS	TRMS	Average	
	10 nA	10 nA	10 nA	100 nA	
	10A	20A	2A	2A	
	0.8%	1.0%	0.8%	1.5%	
Included	Option	Option	Option	—	Included
All functions and features	Range (V, Ω), dB, calibration, relative reference	Trigger, Talk Only	Trigger, Talk Only	—	All functions and features
Front panel or bus	Front panel or bus (w/IEEE option)	—	—	—	Front panel or bus
Auto/Manual	Auto/Manual	Manual	Manual	Manual	Auto/Manual
Rear	Front	Front	Front	Front	Front
—	Optional 6-8 hour	Optional 6 hour	Optional 6 hour	Standard. AC opt.	—
Real time data port. Analog output. Independent time bases. Synchronize up to 8 channels. Five trigger sources.	100-point data logger. dB mode. Relative reference.	1kV protection on Ω. 20A AC, DC current. BCD output option.	1μV, 1nA, 1mΩ sensitivity. Analog output. BCD output option.	Function & range annunciators. 15mm digits. 1-year battery.	Analog output. 10GΩ input impedance. 1024-point buffer.

Technical Data

Digital multimeters convert analog signals to digital information. The typical five-function DMM measures DC volts, DC amps, ohms, AC volts, and AC amps. While specifics may vary, virtually every DMM is developed around the same block diagram (**Figure 1**).

FIGURE 1: DMM Block Diagram

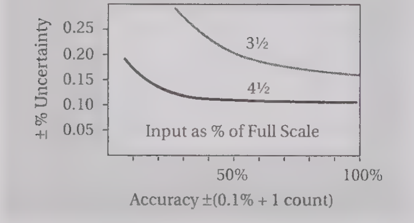


Analog-to-Digital Conversion

The A/D converts the analog input signal to a digital output, and is principally responsible for the key instrument characteristics of reading speed, linearity, resolution, normal mode rejection, and precision. The digital output can be sent to one of several ports including front panel display, or to computer interfaces such as GPIB or RS 232.

Many bench and handheld instruments use a single-chip dual slope conversion circuit for simplicity and convenience. Programmable instruments generally use the capability of the microprocessor and variations on charge balance or successive approximation techniques to achieve higher resolution and speed.

FIGURE 2: Expected Reading Uncertainty: 3½- vs. 4½-Digit DMMs



Resolution

Resolution is defined as the smallest detectable change on any range referenced to full scale. For example, if an instrument will display a maximum value of 1999 on any range, and the smallest detectable change in the input signal is ±1 LSD, then the resolution is 1/1999 or 0.05%.

Resolution is commonly expressed as a whole number plus a fraction, e.g., 4½ digits. The whole number represents the number of digits which can display 0–9. The fraction indicates that the most significant digit has one or more non-zero states; that is, it can display 0, 1, or 2.

Sensitivity

Sensitivity is like resolution in that it deals with the smallest change of the input signal the instrument can detect. However, since sensitivity is not referenced to full scale, it is expressed in absolute terms, and applies to the lowest range on any function. The sensitivity of a 5½-digit DMM is 1µV if the lowest measurement range is 200mV.

Accuracy

Accuracy is specified as ±(% reading + offset counts), and is generally stated under several different conditions including ±1°C, ±5°C operating temperature, and 24-hour, 90-day, and 1-year calibration intervals. The expected accuracy can be improved by controlling temperature variations in the environment and by electing more frequent calibration intervals. **Figure 2** illustrates the effect on accuracy at various levels of input signal within the measurement range. Accuracy for both meters is specified at ±(0.1% + 1 count). The best accuracy is obviously obtained near full scale.

True RMS and Average Responding Meters

DMMs convert AC signals to DC voltages to be measured by the A/D converter. The AC converter may be either a true RMS or an averaging type. Both will respond with the same output value for a sine wave input. However, signals other than sine waves produce an error in the displayed value when measured with an average responding meter.

FIGURE 3: True RMS vs. Averaging DMMs

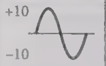
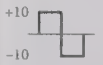
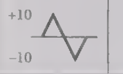
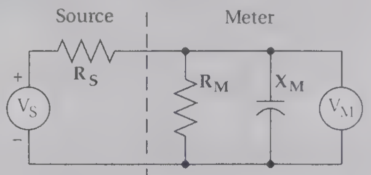
	Waveform	RMS Value of Waveform	True RMS Reading	Average DMM Reading	Error for Average Meter
Sine		7.07V	7.07V	7.07V	0%
Square		10.00V	10.00V	11.11V	11.1%
Triangular		5.77V	5.77V	5.55V	3.8%

FIGURE 4: Loading Error



$$\text{Loading Error} = -\frac{R_S}{R_S + Z_M} \quad \text{and} \quad Z_M = \frac{R_M X_M}{R_M + X_M}$$

Function	Increase	Effect on Loading Error
ACV or DCV	R_S	Increase
ACV or DCV	R_M	Decrease
ACV	C_M	Increase
ACV	Frequency	Increase

Figure 3 illustrates resultant error for three common types of waveforms. For irregular waveforms, it is better to use a true RMS meter.

Loading/Input Impedance

Loading is the disturbance to the circuit being measured caused by the finite input impedance of the DMM. Input impedance is the equivalent resistance and capacitance looking into the DMM at the input terminals.

Loading Error. The difference between the voltage measured by the meter (V_M) and the voltage of an ideal source (V_S) is the loading error (**Figure 4**).

Voltage Burden Error is the difference between the expected current through load R_L and the measured current I_M caused by the finite voltage drop of the measuring instrument (**Figure 5**).

Ohmmeter Full Scale Voltage

This is the voltage that will be present across the measurement circuit when the resistance of the circuit is near full scale. The voltage is developed by the test current flowing through the unknown and the interconnect wiring. When doing in-circuit resistance checks, the full scale voltage should be well below the turn-on voltage of any semiconductor junctions. Some meters have special HI and LO functions for reducing the ohmmeter full scale voltage. In addition, many meters have special diode testing ranges.

2-Wire vs. 4-Wire Ohms (Figure 6).

Two-terminal DMMs source test current through the measuring test leads, terminating at the HI-LO inputs of the DMM. This two-wire ohms system works fine for 3½-digit and most 4½-digit DMMs. However, the I-R drop in the test leads (R_L) can cause inaccuracies that become apparent on 5½-digit models.

Four-wire ohms or Kelvin measurements bypass the voltage drop across R_L by bringing two high impedance voltage sense leads out to the unknown R_X. Since there is very little current in the sense circuit, there is effectively no I-R drop in the leads, and the voltage seen by the sense terminals is the same as the voltage developed across R_X.

Speed and Settling Time

Every meter has a settling time associated with its input circuit. The reading rates or measurement speeds of instruments are independent of the settling times. For high resolution meters, it may be necessary to allow time for input settling in order to achieve full rated accuracy.

Normal and Common Mode Rejection

Normal mode interference is that which is mixed with the incoming signal. Most normal mode interference is at line frequency and its harmonics. NMRR (Normal Mode Rejection Ratio) is specified in dB at line frequencies of 50Hz and 60Hz. Normal mode interference is detected as a peak noise or deviation in a DC signal.

$$\text{NMRR} = 20 \log \frac{\text{(peak measurement deviation)}}{\text{(peak normal mode interference)}}$$

CMRR (Common Mode Rejection Ratio) is the ability of a meter to reject signals common to both input HI and LO. This term is generally measured with a 1kΩ resistor imbalance in one of the leads. Larger imbalance will cause CMRR to be worse. CMRR is specified at either DC, 50Hz or 60Hz, and like NMRR is expressed in dB. CMRR applies to both DC and AC measurements and appears as an offset error to the desired signal.

Digital Calibration

Microprocessor design techniques and non-volatile memories have brought about the ability to calibrate an instrument through computer control. This digital calibration improves reliability by eliminating mechanical trim components, ensures repeatability in procedures by allowing fully automated calibration, and makes it easy under computer control to build history files on individual instruments to determine long term trends.

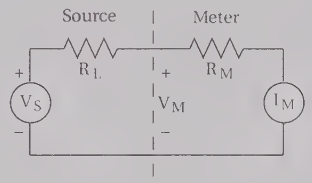
Overload Protection

This is a measure of electrical ruggedness, and should be sufficient to protect the meter from line voltages commonly encountered. Typically, the ranges most susceptible to high voltage are the lowest voltage range (200mV) and the ohms ranges. Similar to overload protection is the maximum common mode voltage at which the meter can be used. This is the maximum voltage from earth ground that the input LO or COMMON terminal can withstand safely. The input LO terminal should always be at the lowest impedance point to minimize ground loops, and whenever possible should be connected to circuit COMMON for safety.

Power

Many Keithley DMMs have provisions for field installation of a rechargeable battery pack. This assures isolation from the power line and allows some degree of portability.

FIGURE 5: Voltage Burden Error

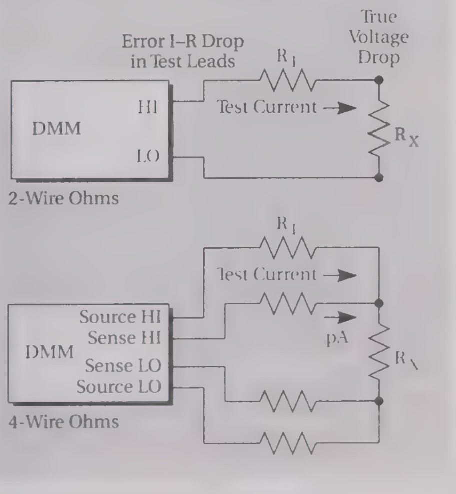


1. $I_S = \frac{V_S}{R_L}$ for $V_M = 0$ 2. $I_M = \frac{V_S - V_M}{R_L}$

Voltage Burden Error $= \frac{I_M - I_S}{I_S} = -\frac{V_M}{V_S}$

$V_M \propto \frac{I_M}{I_{FS}} V_B$ where V_B is the maximum burden voltage and I_{FS} is the full scale current.

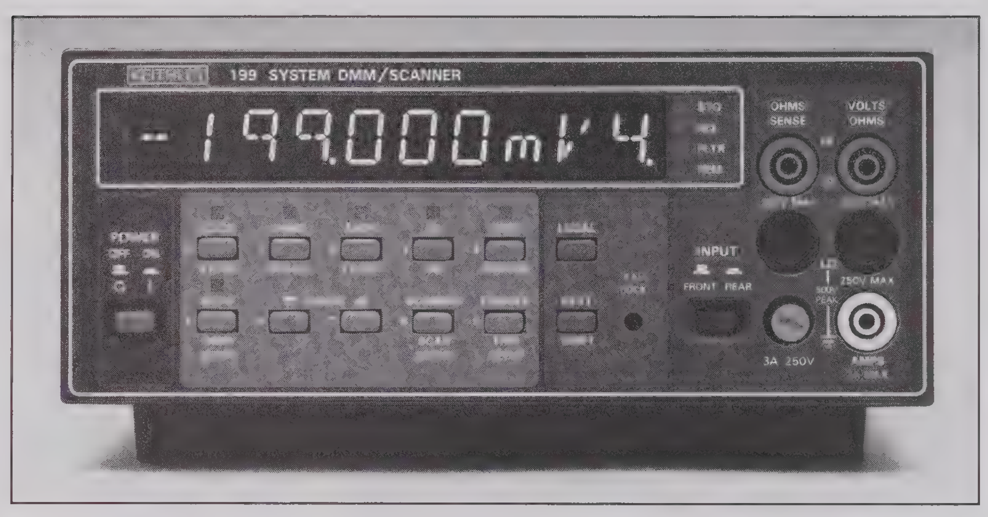
FIGURE 6: 2-Wire vs. 4-Wire Ohms



5½-Digit DMM

- Excellent accuracy and AC measurements
- Full 300,000 count measurements
- 150 readings/second
- 500-reading memory
- 2-year warranty
- 1µV, 100nA, 1mΩ sensitivities

IEEE-488


199 SYSTEM DMM/SCANNER
-199.000mV 4
OHMS SENSE
VOLTS OHMS
INPUT
FRONT REAR
250V MAX
3A 250V
AMPS

ORDERING INFORMATION

199
System DMM with Instruction Manual and Model 1751 Safety Test Leads

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS	
1681	Clip-On Test Lead Set
1751	Safety Test Leads
1754	Safety Universal Test Lead Kit
5806	Kelvin Test Leads
PROBES/SHUNT	
1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe
CABLES	
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
RACK MOUNT KITS	
1998-1	Single Fixed Rack Mount Kit
1998-2	Dual Fixed Rack Mount Kit
OTHER	
1992	8-Channel Scanner Option

See page 163 for descriptions of all accessories.

The Model 199 is a 5½-digit system DMM in a compact, half-rack package. The DMM features six standard measurement functions—DC and AC volts, DC and AC amps, ohms (2- and 4-wire), and dB (for AC volts and amps) along with the IEEE-488 interface.

More Performance, Maximum Utility

Sensitivities are 1µV, 1mΩ, and 100nA with 60 ppm basic 90-day accuracy in DC volts. AC voltage accuracies are good to <1% of full scale, much better than competitive units. Enhancements include a digital FILTER for noise reduction and a ZERO function to subtract offsets or make measurements referenced to a specific baseline. The Model 199's functions and features can be pre-set for power-up, and the display can be programmed with operator messages.

Fast—Where it Counts

The Model 199 has the speed for a high-performance test system. It can be externally triggered to meet system timing requirements at up to 150 readings/second with 4½-digit resolution. By storing the readings in its 500-point memory, the 199 frees the system controller from real-time data collection. In addition, the Model 199 can reduce bus communication time with Keithley's TRANSLATOR software (see explanation under Model 193A).

Stand-Alone Data Logging

Use the Model 199 to track drift or other trends. The 199 can be programmed to automatically store up to 500 readings at intervals from 15ms to 16.6 minutes (over 5 days of data), or by external trigger.

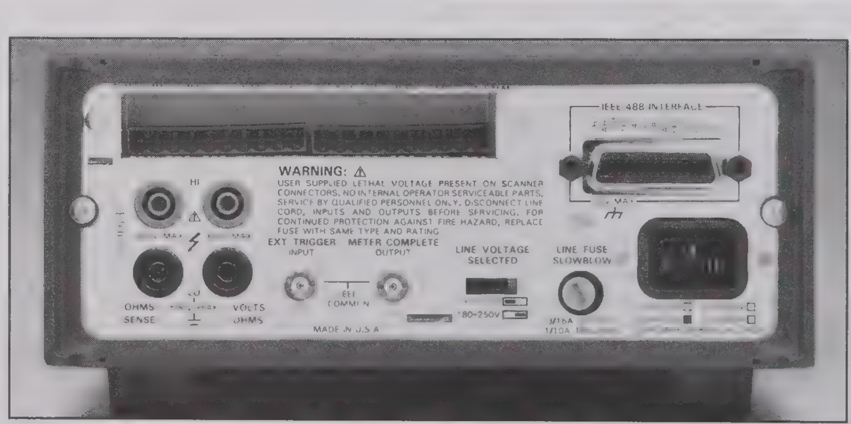
IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and programs are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, Terminator, Display Message, and Non-Volatile TRANSLATOR. IEEE-488 address is programmable from the front panel.


IEEE 488 INTERFACE
WARNING: ⚠
USER SUPPLIED LETHAL VOLTAGE PRESENT ON SCANNER CONNECTORS. NO INTERNAL OPERATOR SERVICEABLE PARTS, SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD, INPUTS AND OUTPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH SAME TYPE AND RATING
HI
EXT TRIGGER INPUT
METER COMPLETE OUTPUT
EXT COMMON
LINE VOLTAGE SELECTED
LINE FUSE SLOWBLOW
OHMS SENSE
VOLTS OHMS
180-250V
MADE IN U.S.A.

5½-Digit DMM 199

DC AMPS [illegible]

RANGE	RESOLUTION	ACCURACY [illegible]	MAXIMUM VOLTAGE BURDEN
30 mA	100 nA	0.05 + 15	0.4 V
3 A	10 µA	0.1 + 15	2 V

[1] For 4½-digit accuracy, count error is 20.

MAXIMUM ALLOWABLE INPUT: 3A. Protected with 3A, 250V fuse accessible from front panel.

TRMS AC AMPS [illegible]

RANGE	RESOLUTION	ACCURACY [illegible] [illegible]		MAXIMUM VOLTAGE BURDEN
		[illegible]	[illegible]	
30 mA	100 nA	2 + 100	0.6 + 100	0.4 V
3 A	10 µA	2 + 100	0.6 + 100	2 V

dB [illegible]

INPUT	RESOLUTION	ACCURACY ±dB 1 Year, 18°–28°C 20 Hz–10 kHz
–14 to +69 dB (200 µA to 3 A)	0.01 dB	0.6

[1] Inputs >2000 counts. For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at ⅔ full range.

NON-SINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz.

MAXIMUM ALLOWABLE INPUT: 3A. Protected with 3A, 250V fuse accessible from front panel.

SETTLING TIME: 1 second to within 0.1% of final reading.

STORAGE CAPABILITIES

500-READING MEMORY: Stores reading, range, and scanner channel.

TRIGGER: One shot or continuous from front panel, IEEE-488 bus, and rear panel BNC.

PROGRAMMABLE READING INTERVAL: 15ms to 999.999s.

PROGRAMMABLE TRIGGER DELAY: 1ms to 999.999s.

[illegible]

MAXIMUM READING: 302,999 counts in 5½-digit mode.

CONNECTORS: Measurement: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and METER COMPLETE output on rear panel, BNCs.

WARM-UP: 2 hours to rated accuracy.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification)/°C.

ISOLATION: Input LO to IEEE LO or power line ground: 500V peak. 5 × 10⁵ V•Hz maximum. >10⁹Ω paralleled by 400pF.

OPERATING ENVIRONMENT: 0°–50°C, 80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°–50°C (0%-60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: –25° to +65°C.

POWER: 105–125V or 210–250V, rear panel switch selected, 50Hz or 60Hz, 20VA maximum. 90–110V and 180–220V versions available upon request.

DIMENSIONS, WEIGHT: 90mm high × 220mm wide × 330mm deep (3½ in. × 8⅝ in. × 12⅞ in.). Net weight 3kg (6 lbs., 8 oz.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, instruction manual.

DC VOLTS [illegible]

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY [illegible]		
			[illegible]	[illegible]	[illegible]
300 mV	1 µV	>1 GΩ	0.004 + 3[3]	0.009 + 3[3]	0.012 + 3[3]
3 V	10 µV	>1 GΩ	0.003 + 2	0.006 + 2	0.007 + 2
30 V	100 µV	11 MΩ	0.004 + 2	0.008 + 2	0.009 + 2
300 V	1 mV	10 MΩ	0.004 + 2	0.008 + 2	0.009 + 2

[1] For 4½-digit accuracy, count error is 5 (except 15 on 300mV range).
[2] Relative to calibration standards. [3] When properly zeroed.

CMRR: >120dB at DC, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, whichever is less.

TRMS AC VOLTS [illegible]

RANGE	RESOLUTION	ACCURACY [illegible]			
		[illegible]	[illegible]	[illegible]	[illegible]
300 mV	1 µV	2 + 100	0.35 + 100	0.15 + 200	2.0 + 300
3 V	10 µV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
30 V	100 µV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300

dB [illegible]

INPUT	RESOLUTION	[illegible]	
		[illegible]	[illegible]
–34 to +49 dB (20 mV to 300 V)	0.01 dB	0.2	0.4
–54 to –34 dB (2 mV to 20 mV)	0.01 dB	1.1	—

[1] For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.
[2] Sinewave inputs >2000 counts. [3] Sinewave inputs >20,000 counts.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NON-SINUSOIDAL INPUTS (>20,000 counts): For rectified sine wave, add 0.3% of reading to above specifications for fundamental frequencies <20kHz. For pulse waveforms, add 0.3% of reading for fundamental frequencies <1kHz, or 3.5% for frequencies <10kHz.

INPUT IMPEDANCE: 1MΩ shunted by <100pF.

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, 10⁷V•Hz, whichever is less.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

SETTLING TIME: 1 second to within 0.1% of change in reading.

OHMS [illegible]

RANGE	RESOLUTION	NOMINAL I SHORT	ACCURACY [illegible]		
			24 Hour [illegible]	90 Day [illegible]	[illegible]
300 Ω[2]	1 mΩ	1.7 mA	0.005 + 4[3]	0.009 + 4[3]	0.012 + 4[3]
3 kΩ[2]	10 mΩ	1.7 mA	0.004 + 2	0.008 + 3	0.009 + 3
30 kΩ[2]	100 mΩ	160 µA	0.004 + 2	0.008 + 3	0.009 + 3
300 kΩ	1 Ω	50 µA	0.014 + 2	0.024 + 3	0.026 + 3
3 MΩ	10 Ω	5 µA	0.02 + 2	0.03 + 3	0.03 + 3
30 MΩ	100 Ω	0.5 µA	0.1 + 5	0.12 + 5	0.12 + 5
300 MΩ	1 kΩ	0.5 µA	2.0 + 5	2.0 + 5	2.0 + 5

[1] For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range).
[2] 4-wire accuracy, 300Ω–30kΩ ranges. [3] When properly zeroed. [4] Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire.

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: <5.5V.

MAXIMUM READING RATES [illegible]

DCV, DCA, ACV, ACA	Continuous Into Memory		External Trigger Into Memory		Triggered via IEEE-488 Bus[2]	
RESOLUTION	**MUX Off**	**MUX On**	**MUX Off**	**MUX On**	**MUX Off**	**MUX On**
4½-Digit	65	65	150	62	80	49
5½-Digit	35 (29)	9 (7½)	40 (33)	9 (7½)	34 (29)	9 (7½)
OHMS	**Continuous Into Memory**		**External Trigger Into Memory**		**Triggered via IEEE-488 Bus[2]**	
RESOLUTION	**MUX Off**	**MUX On**	**MUX Off**	**MUX On**	**MUX Off**	**MUX On**
4½-Digit	43	20	47	20	30	18
5½-Digit	16 (13)	9 (7½)	18 (15)	9 (7½)	15 (12½)	9 (7½)

[1] Reading rates are for fixed range readings with filters off, for 3V, 3kΩ, and 30mA ranges. 5½-digit rate is for 60Hz operation. Values in parentheses are for 50Hz operation.
[2] One shot on TALK.

199/1992 5½-Digit DMM/Scanner

- **Built-in 8-channel scanner**
- **Switch and measure 40 channels/second**
- **2- or 4-pole measurements**
- **Reduced bus communication time**

[illegible]

199/1992
System DMM with 8-Channel Scanner Option, Instruction Manual, 1751 Safety Test Leads, 1993 Quick Disconnect Scanner Connector Kit

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

TEST LEADS

1681	Clip-On Test Lead Set
1751	Safety Test Leads
1754	Safety Universal Test Lead Kit
1993	Quick Disconnect Scanner Connector Kit
5806	Kelvin Test Leads

PROBES/SHUNT

1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

RACK MOUNT KITS

1998-1	Single Fixed Rack Mount Kit
1998-2	Dual Fixed Rack Mount Kit

OTHER

1992	8-Channel Scanner Option

See page 163 for descriptions of all accessories.

Convert the 199 Into a Complete Measurement System

Add the factory- or field-installable Model 1992 8-Channel Scanner option to the 199 System DMM and automatically switch and measure multiple points with one instrument. Each set of contacts creates less than 1μV thermal contact error. Thus the scanner can make low-level 4-wire measurements on 4 channels as well as 2-pole measurements on 8 channels. With the scanner option, ratios can be measured and displayed directly.

The DMM/Scanner combination can switch and measure at up to 40 channels/second. Acquire data three ways:

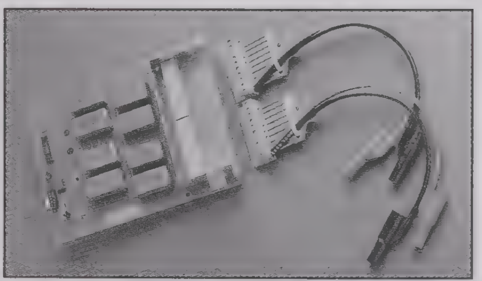
1. *Manual*: Switch channels from the front panel.
2. *Step*: Automatically increment through each channel at a defined interval.
3. *Scan*: Automatically scan a set of channels at a defined interval. The scan mode is excellent for near-simultaneous trend recording of multiple points.

Savings Through Integration

The Model 199 with the scanner option saves more than just the price of one extra instrument. You also save rack space, and start-up time is reduced since you learn to program a single instrument instead of two. Program execution time is also reduced since bus communications occur with one and not two instruments. Finally, save on maintenance costs—the 199/1992 has a 2-year warranty.

The 1992 8-Channel Scanner Option is field-installable and can therefore be purchased at any time. Maintain individual wiring setups with the Model 1993 Quick Disconnect Scanner Connector Kit (included with the 1992 and also available separately) and save system assembly time.

IEEE-488



Model 1992 8-Channel Scanner Option includes a pair of Model 1993 Quick Disconnects.

MODEL 1992 SCANNER OPTION

CONTACT CONFIGURATION: 8-channel 2-pole, or 4-channel 4-pole; break-before-make.

CONTACT POTENTIAL: <1μV per contact pair.

MAXIMUM SWITCHING RATE: 40 channels/second, including Model 199 4½-digit DCV reading time.

CONNECTOR TYPE: Quick disconnect screw terminals, #14 AWG maximum wire size.

MAXIMUM SIGNAL LEVEL: 200V peak, 100mA, resistive load.

CONTACT LIFE: $>10^6$ operations (at maximum signal level); $>10^8$ operations (cold switching).

CONTACT RESISTANCE: <1Ω.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^9\Omega$, <75pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9\Omega$, <150pF.

COMMON MODE VOLTAGE: 350V peak between any terminal and earth.

MAXIMUM VOLTAGE BETWEEN ANY TWO TERMINALS: 200V peak.

MAXIMUM VOLTAGE BETWEEN ANY TERMINAL AND MODEL 199 INPUT LO: 200V peak.

DIMENSIONS, WEIGHT: 25mm high × 130mm wide × 170mm deep (⅞ in. × 5 in. × 6½ in.). Adds 0.3kg (8 oz.) to Model 199.

SCANNING CAPABILITIES

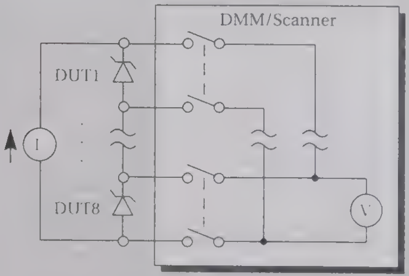
PROGRAMMABLE CONFIGURATION: 2- or 4-pole.

PROGRAMMABLE CHANNEL LIMIT: 1 to 8.

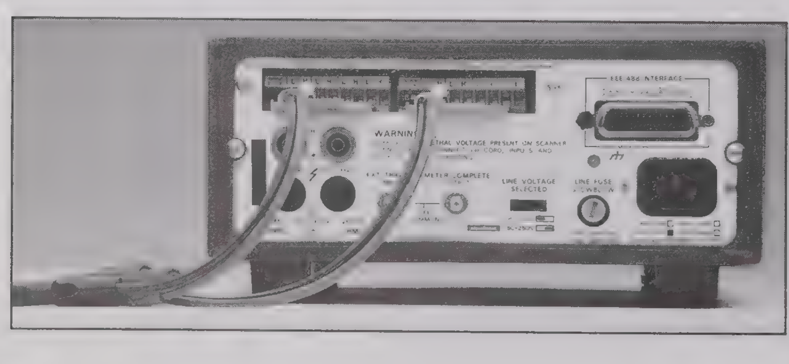
PROGRAMMABLE SCANNING MODES: Manual, step, and scan.

RATIO: Channels 2 through 8 referenced to Channel 1.

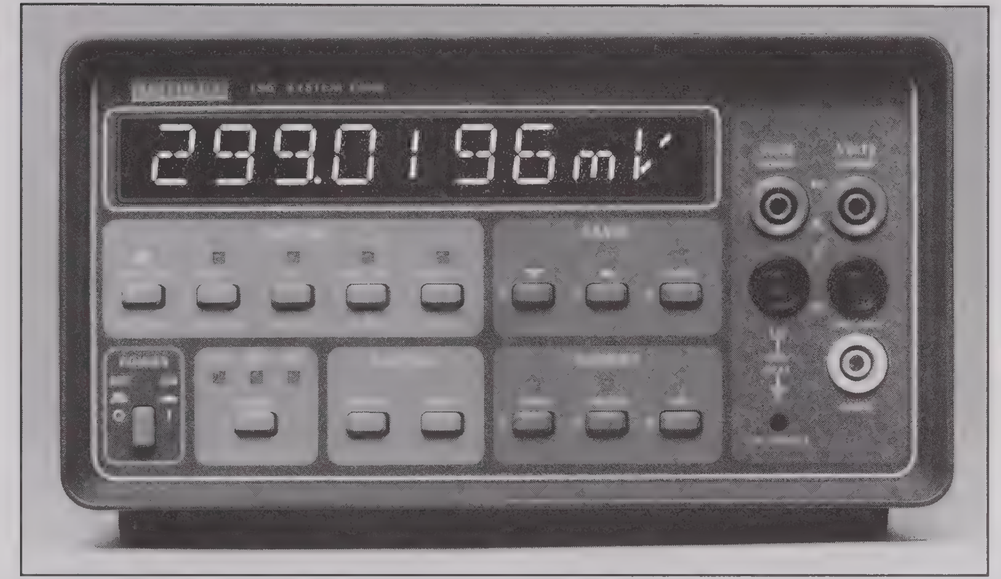
See page 25 for complete Model 199 System DMM specifications.



Use the Model 199 DMM/Scanner to evaluate multiple components, such as zener diodes, in a single test.



6½-Digit DMM



- 100nV, 100μΩ, 1nA sensitivities
- Up to 1000 readings/second
- Offset compensated Ω
- 10ppm linearity

IEEE-488

[illegible]

196
System DMM (3½- to 6½-Digit) with Instruction Manual, Model 1751 Safety Test Leads

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible] AVAILABLE

TEST LEADS	
1681	Clip-On Test Lead Set
1751	Safety Test Leads
1754	Safety Universal Test Lead Kit
5806	Kelvin Test Leads
CABLES	
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
PROBES/SHUNT	
1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe
RACK MOUNT KITS	
1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

See page 163 for descriptions of all accessories.

The fully IEEE-488 programmable Model 196 System DMM packages high resolution, high sensitivity, and high measurement speed into a compact half-rack enclosure. All five basic functions (DCV, ACV, DCA, ACA, and ohms) as well as programmability are standard.

Resolve 1/3 ppm

Whether developing and testing the next generation of components which have tighter tolerances and increased sensitivities, or researching a low level phenomenon, you need high levels of resolution and sensitivity in your DMM. The Model 196 meets your needs with a 6½-digit, 3,000,000 count display. At full scale the last digit represents a very small ⅓ppm.

Detect Small Changes

The 196 provides excellent sensitivity in not only voltage and resistance but also current. You can resolve 1μV in 3 volts, 1mΩ in 3kΩ, and 10nA in 3mA. In addition to high resolution, basic 90-day DCV accuracy is 30ppm.

Enhance Measurement Quality

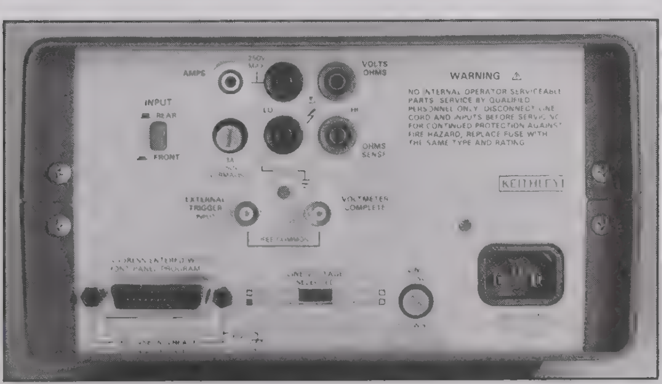
Special features enable you to obtain the most from the 196's resolution and sensitivity. Eliminate thermal effects that can create errors in low level resistance measurements with offset compensated ohms. Control the programmable digital filtering levels to compensate for external noise. Eliminate offsets with the programmable ZERO function. Independent zero and filter levels can be established for each function; the 196 stores these parameters separately.

High Speed for High Throughput

Capture low frequency phenomena of any wave shape at 1000 readings/second at 3½-digit resolution. At 4½-digit resolution acquire 333/second. In system applications the 196 can be triggered to take 200/second at 3½ digits. When reading speeds exceed the rate at which they can be handled over the IEEE-488 bus, readings can be stored in the 196's 500-reading buffer.

Eases the System Integration Task

Keithley's exclusive TRANSLATOR software enables you to substitute your own mnemonics for the 196's device-dependent command strings. The mnemonics use fewer characters, making your code more readable and reducing bus activity. TRANSLATOR also provides emulation capability which lets you upgrade your system by using the 196 to replace an older DMM without making major changes to your software. The TRANSLATOR commands are retained in nonvolatile memory, so the 196 needs to be programmed only once.


AMPS
250V MAX
VOLTS OHMS
INPUT
REAR
FRONT
LO
HI
OHMS SENSE
WARNING
NO INTERNAL OPERATOR SERVICEABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD AND INPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING.
KEITHLEY
EXTERNAL TRIGGER INPUT
VOLTMETER COMPLETE

196 6½-Digit DMM

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TEMPERATURE COEFFICIENT [illegible]
300 mV	100 nV	>1 GΩ	0.0020 + 20[3]	0.005 + 20[3]	0.008 + 20[3]	0.0006 + 10
3 V	1 µV	>1 GΩ	0.0013 + 10	0.003 + 20	0.0038 + 20	0.0004 + 1
30 V	10 µV	11 MΩ	0.0015 + 10	0.006 + 20	0.008 + 30	0.0013 + 3
300 V	100 µV	10.1MΩ	0.003 + 10	0.009 + 20	0.009 + 30	0.0013 + 1

[1] For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300mV range). For 3½-digit accuracy, count error is 5.

[2] Relative to calibration standards.

[3] When properly zeroed.

ANALOG SETTLING TIME: <1ms (<2ms on 300mV range), to 0.01% of step change.

CMRR: >120dB at DC, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 10ppm of range for 3V–300V ranges; 15ppm of range for 300mV range; at 23°C ±1°C.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300 mV	1 µV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	2.0 + 300
3 V	10 µV	2 + 100	0.3 + 100	0.15 + 100	0.3 + 200	1.5 + 300
30 V	100 µV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300
300 V	1mV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300

[illegible]	[illegible]	[illegible]	[illegible]
–34 to +49 dB (20mV to 300V)	0.2	0.4	0.01 dB
–54 to –34 dB (2mV to 20mV)	1.1	3[4]	0.01 dB

[1] For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for inputs >200Hz.

[2] For sinewave inputs >2,000 counts.

[3] For sinewave inputs >20,000 counts.

[4] Typical.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NON-SINUSOIDAL INPUTS: For fundamental frequencies <1kHz, crest factor <3, add 0.25% of reading to specified accuracy for 300mV and 3V ranges; add 0.6% of reading to specified accuracy for 30V and 300V ranges.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

3dB BANDWIDTH: 300kHz typical.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, 10^7V•Hz, whichever is less.

SETTLING TIME: 1 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification) / °C below 20kHz, ±(0.2×) for 20kHz to 100kHz.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

RANGE	RESOLUTION	[illegible]	[illegible]
300 µA	1 nA	0.09 + 20	0.4 V
3 mA	10 nA	0.05 + 10	0.4 V
30 mA	100 nA	0.05 + 10	0.4 V
300 mA	1 µA	0.05 + 10	0.5 V
3 A	10 µA	0.09 + 10	2 V

[1] 4½-digit count error is 20. 3½-digit count error is 5.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V), accessible from rear panel.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification) / °C.

RANGE	RESOLUTION	[illegible]	[illegible]	[illegible]
300 µA	1 nA	2 + 100	0.9 + 100	0.4 V
3 mA	10 nA	2 + 100	0.6 + 100	0.4 V
30 mA	100 nA	2 + 100	0.6 + 100	0.4 V
300 mA	1 µA	2 + 100	0.6 + 100	0.5 V
3 A	10 µA	2 + 100	0.6 + 100	2 V

[illegible]	[illegible]	[illegible]
–34 to +69 dB (20µA to 3A)	0.2	0.01 dB
–54 to –34 dB (2µA to 20µA)	0.9	0.01 dB

[1] For sinewave inputs >2000 counts. For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for sinewave inputs >200Hz.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at 2/3 full scale.

NON-SINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz, crest factor <3.

SETTLING TIME: 1 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V) accessible from rear panel.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification) / °C.

6½-Digit DMM 196

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Reading Storage, Calibration, Display, Multiplex, Status, Service Request, Self Test, Output Format, TRANSLATOR.

FRONT PANEL PROGRAMS

0	Menu
2	Display Resolution
4	mX + b
5	Hi/Lo/Pass
6	Multiplex On/Off
30	Save Setup
31	IEEE-488 Address
32	Line Frequency
33	Self Test
34	Set m, B Constants
35	Set Hi/Lo Limits
36	Digital Calibration
37	Reset to factory default conditions
Ω	Offset Compensation
ZERO	Zero Modify
FILTER	Filter Constants
dB	dB Reference

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 3,029,999 counts in 6½-digit mode.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

WARM-UP: 2 hours to rated accuracy.

DISPLAY: 10, 0.5-in. alphanumeric LED digits with decimal point and polarity. Function and IEEE-488 bus status also indicated.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5 × 10^5 max. V•Hz product. >10^9Ω paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 readings/second (2/second on 30MΩ and 300MΩ ranges).

FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

OPERATING ENVIRONMENT: 0°–50°C, 0%–80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°C–50°C (0%–60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: –25° to +65°C.

POWER: 105–125V or 210–250V, rear panel switch selected, 50Hz or 60Hz, 30VA max. 90–110V and 180–220V versions available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.7kg (8 lbs.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, instruction manual.

OHMS

RANGE	RESOLUTION	CURRENT SOURCE	ACCURACY [illegible] 24 Hr.	[illegible] 90 Days	1 Year	TEMPERATURE COEFFICIENT [illegible]
300 Ω [2]	100 µΩ	1.7 mA	0.0025+20[3]	0.008+20[3]	0.010+20[3]	0.001 + 7
3 kΩ [2]	1 mΩ	1.7 mA	0.0025+20	0.005+20	0.007+20	0.001 + 1
30 kΩ [2]	10 mΩ	160 µA	0.0025+20	0.005+20	0.007+20	0.001 + 1
300 kΩ	100 mΩ	50 µA	0.006 +20	0.020+20	0.021+20	0.004 + 1
3 MΩ	1 Ω	5 µA	0.007 +20	0.020+20	0.021+20	0.004 + 1
30 MΩ	10 Ω	0.5 µA	0.06 +50	0.1 +50	0.1 +50	0.030 + 1
300 MΩ [4]	1 kΩ	0.5 µA	2.0 +5	2.0 +5	2.0 +5	0.30 + 1

[1] For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range). For 3½-digit accuracy, count error is 5.

[2] 4-wire accuracy, 300Ω-30kΩ ranges.

[3] When properly zeroed.

[4] Resolution on 300MΩ range is limited to 5½ digits.

[5] Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire. Offset compensation available on 300Ω-30kΩ ranges, requires proper zeroing. Allowable compensation of ±10mV on 300Ω range and ±100mV on 3kΩ and 30kΩ ranges.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: 5.5V maximum.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 300Ω–30kΩ ranges, at 23°C ±1°C.

MAXIMUM READING RATES[1]

DCV, DCA, ACV, ACA READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	1000	1000	237	80	112	58
4½-Digit	333	333	145	63	91	49
5½-Digit	35 (29)	9 (7½)	40 (33)	9 (7½)	35 (29)	9 (7½)
6½-Digit[2]		9 (7½)		0.3 (¼)		0.3 (¼)

OHMS READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	53	25	57	25	37	23
4½-Digit	43	20	47	21	30	19
5½-Digit	16 (13)	9.5 (7½)	18 (15)	9.5 (7½)	15 (12½)	9.5 (7½)
6½-Digit[2]		9 (7½)		0.3 (¼)		0.3 (¼)

Offset Compensated Ohms: Rates are 0.5 × normal mux on ohms rates.

[1] Reading rates are for on-range on-scale readings with internal filter off, for 3V, 3kΩ, and 3mA ranges. 6½- and 5½-digit rates are for 60Hz operation. Values in parentheses are for 50Hz operation.

[2] Internal filter on.

5½-Digit DMM

- 1μV, 1mΩ, 1nA sensitivity
- TRMS AC measurements to 100kHz
- 100-point data logger, relative reference, dB
- IEEE-488 and analog output option
- Backlit display

IEEE-488

ORDERING INFORMATION

All include Instruction Manual and Model 1751 Safety Test Leads.

197A Autoranging Microvolt DMM

197A/1972A Autoranging DMM with IEEE-488 Interface and Analog Output

197A/1973A Autoranging DMM with IEEE-488 Interface

197A/1978 Autoranging DMM with Rechargeable Battery Pack

197A/72/78 Autoranging DMM with IEEE-488 Interface, Analog Output and Rechargeable Battery Pack

197A/73/78 Autoranging DMM with IEEE-488 Interface and Rechargeable Battery Pack

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS

1681	Clip-On Test Lead Set
1751	Safety Test Leads
1754	Safety Univ. Test Lead Kit
5806	Kelvin Clip Leads

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

PROBES/SHUNT

1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe

OUTPUTS

1972A	IEEE-488 Interface with Analog Output
1973A	IEEE-488 Interface

POWER

1978	Rechargeable Battery Pack

RACK MOUNT KITS

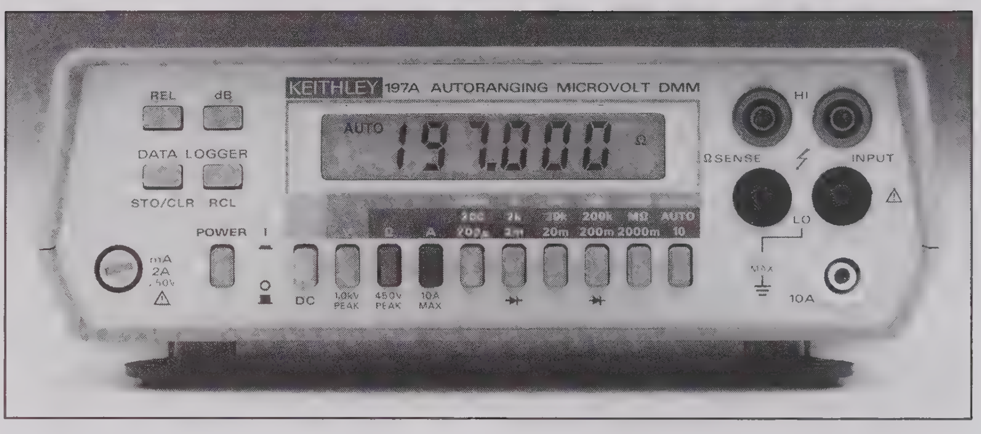
1010	Single Fixed Rack Mount Kit
1017	Dual Fixed Rack Mount Kit

CARRYING CASES

1684	Hard Shell Carrying Case
1686	Vinyl Carrying Case

OTHER

1979	Spare Parts Kit



The Model 197A combines 5½-digit resolution (on a 220,000-count display) with 1μV, 1nA, 1mΩ sensitivity. Basic DCV accuracy is 0.011%.

Extended Performance

Measure voltage over 9 decades from 1μV to 1000V. Input resistance on the two lowest voltage ranges exceeds 1GΩ. TRMS AC measurements can be made to 100kHz. Make 2- or 4-terminal ohms measurements over 11 decades from 1mΩ to 220MΩ. Six current ranges measure from 1nA to 10A.

The microprocessor-based 197A is loaded with smart features. Display annunciators indicate the measurement mode and units. Autoranging on V, Ω, and dB automatically displays maximum resolution.

dB Ranges

Audio and communication circuit analysis is easy with direct-reading dB measurements referenced to 50, 75, 93, 135, 300 or 600 ohms. Resolution is 0.01dB above 1mV.

Pushbutton relative reference (REL) nulls out or zeros on-range readings. REL can also null out circuit voltage offsets or lead resistances and create a new baseline for differential measurements. REL works with the dB function to establish the 0dB point or to make convenient amplifier stage gain comparisons.

The DATA LOGGER stores up to 100 readings at 6 automatic rates from 3 per second to 1 per hour, or manually at the touch of a button. Minimum and maximum readings are continuously updated (3 per second) in the DATA LOGGER mode.

Digital Calibration

Calibration factors for each range are stored in a non-volatile RAM. Without potentiometers to adjust, repeatable calibration is fast and easy.

Powerful Options

Combine IEEE-488 interface with real-time analog monitoring with the 1972A Analog/IEEE Output option. The TALK/LISTEN interface has range programmability on volts and ohms. The smart features, dB, REL, digital calibration, and DATA LOGGER are available over the bus. The analog output has selectable gain of ×1 or ×1000. The REL feature zeros the analog output as well as the display. The IEEE-488 interface alone is also available as the 1973A option.

The 1978 battery pack option enables data to be collected in the field with the DATA LOGGER and processed back in the lab by transferring the data to an IEEE-compatible printer.

See page 163 for descriptions of all accessories.

5½-Digit DMM 197A

DC VOLTS

RANGE	RESOLUTION	INPUT RESISTANCE**	ACCURACY* ±(%rdg + counts) 24 Hr. [illegible]	1 Year 18°–28°C
200mV	1 µV	>1 GΩ	0.007 + 2	0.016 + 3
2 V	10 µV	>1 GΩ	0.005 + 2	0.011 + 2
20 V	100 µV	11 MΩ	0.006 + 2	0.015 + 3
200 V	1 mV	10 MΩ	0.006 + 2	0.015 + 2
1000 V	10 mV	10 MΩ	0.007 + 2	0.015 + 2

*Relative to calibration accuracy. **When properly zeroed.

NMRR: >60dB at 50Hz, 60Hz ±0.1%.

MAXIMUM ALLOWABLE INPUT: 1000V DC or peak AC (<10 seconds per minute on 200mV and 2V ranges; 300V rms continuous).

SETTLING TIME: 1 second to within 3 counts of final reading on range.

dB MODE (ref: 600Ω): Accuracy: ±(0.02dB+1 count) above –78dBm. **Resolution:** 0.01dB above 5% of range.

DC AMPS

RANGE	RESOLUTION	MAXIMUM VOLTAGE BURDEN	ACCURACY [illegible]
200 µA	1 nA	0.3 V	0.1 + 15
2 mA	10 nA	0.3 V	0.1 + 15
20 mA	100 nA	0.3 V	0.1 + 15
200 mA	1 µA	0.3 V	0.2 + 15
2000 mA	10 µA	0.8 V	0.2 + 15
10 A	100 µA	0.3 V	0.5 + 15*

*Above 5A derate 0.15% rdg per amp for self-heating.

OVERLOAD PROTECTION: mA Input: 2A fuse (250V), externally accessible. **10A Input:** 20A for 15s, unfused.

SETTLING TIME: 1 second to within 3 counts of final reading.

ANALOG/IEEE OUTPUT [illegible]

ANALOG OUTPUT:
- **Accuracy:** ±(0.25% of displayed reading + 2mV).
- **Response Time:** Follows display conversion rate.
- **Level:** 1V=100,000 counts on ×1 gain. 1V=100 counts on ×1000 gain. Maximum output voltage = 4V.
- **Output Resistance:** 1000Ω.
- **Isolation:** 500V peak, Input LO to Output LO. 30V peak, output LO to earth ground.

IEEE OUTPUT: See IEEE BUS IMPLEMENTATION.

IEEE BUS IMPLEMENTATION

[illegible]

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, REL, dB, EOI, Trigger, Calibration, SRQ, Status, Output Format, Terminator, Data Logger Retrieval.

TRMS AC VOLTS

RANGE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
200 mV	1.00 + 100	0.35 + 100	0.6 + 200	1.5 + 250	5 + 400
2V–200V	1.00 + 100	0.35 + 100	0.6 + 200	1.5 + 250	3 + 400
750 V	1.25 + 100	0.75 + 100	1.0 + 200	1.8 + 250	3 + 400

dB MODE RANGE	INPUT	[illegible]	[illegible]	[illegible]	[illegible]
2V–750V	200 mV to 750 V (–12 to 59.8dBm)	0.18	0.18	0.28	0.50
200 mV	20 mV to 200 mV (–32 to –12dBm)	0.18	0.18	0.28	0.65
	2 mV to 20 mV (–52 to –32dBm)	0.85	1.10	2.00	—
	1 mV to 2 mV (–58 to –52dBm)	2.00	3.00	—	—

Resolution: 0.01dB above 0.5% of range.

*Above 1800 counts. **Above 18000 counts.

MAXIMUM ALLOWABLE INPUT: 750V rms, 1000V peak (<10 seconds per minute on 200mV and 2V ranges; 300V rms continuous). 10^7V•Hz maximum.

3dB BANDWIDTH: 300kHz typical.

INPUT IMPEDANCE: 1MΩ paralleled by <75pF on 200V and 750V ranges; 1.1MΩ on 200mV, 2V, and 20V ranges. Capacitively coupled.

SETTLING TIME: 1 second to within 0.1% of final reading on range.

db REFERENCE IMPEDANCE: 50, 75, 93, 135, 300 or 600 ohms, front panel selectable.

TRMS AC AMPS

RANGE	MAXIMUM VOLTAGE BURDEN	[illegible]	[illegible]	[illegible]
200µA–20mA	0.3 V	1.0 + 100	0.8 + 100	2 + 250
200 mA	0.3 V	1.0 + 100	0.8 + 100	—
2000 mA	0.8 V	1.0 + 100	0.8 + 100	—
10 A	0.3 V	1.5 + 100	1.0 + 100**	—

*Above 1800 counts. **1kHz max. Above 5A derate 0.15% rdg/amp for self-heating.

SETTLING TIME: 1 second to within 0.1% of final reading.

OHMS

RANGE	RESOLUTION	TEST CURRENT	[illegible]	[illegible]	[illegible]
200 Ω	1 mΩ	2 mA	0.5 V	0.01 + 2*	0.018 + 3*
2 kΩ ▶|	10 mΩ	2 mA	4.0 V	0.01 + 2	0.018 + 2
20 kΩ	100 mΩ	400 µA	4.0 V	0.014 + 2	0.026 + 2
200 kΩ ▶|	1 Ω	40 µA	4.0 V	0.014 + 2	0.026 + 2
2 MΩ **	10 Ω	4 µA	4.0 V	0.02 + 2	0.035 + 2
20 MΩ **	100 Ω	400 nA	4.0 V	0.10 + 2	0.12 + 2
200 MΩ **	10 kΩ	400 nA	5.0 V	2.00 + 1	2.00 + 1

*When properly zeroed. **Appropriate range selected automatically in MΩ.

CONFIGURATION: Automatic 2 or 4-terminal.

MAXIMUM ALLOWABLE INPUT: 450V DC or peak AC 10 seconds per minute. 350V rms continuous.

OPEN CIRCUIT VOLTAGE: +5V.

DIODE TEST: Display reads junction voltage up to 2.2V. Test Current: 1.6mA nominal.

SETTLING TIME: 2 seconds to within 3 counts of final reading on range.

GENERAL

DISPLAY: Backlit ±220,000-count LCD, 0.45 in. height; polarity, function, range, and status indication. Backlighting is switch selectable.

RANGING: Auto or manual on DC volts, AC volts, and ohms; manual on AC amps and DC amps.

AUTORANGING TIME: 300ms per range average.

RELATIVE: Pushbutton allows zeroing of on range readings. Allows readings to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATALOGGER and MIN/MAX: 100 reading storage capacity; records data at one of six selectable rates from 3 readings/second to 1 reading/hour or by manual triggering. Also detects and stores maximum and minimum readings continuously while in data logger mode.

CONVERSION RATE: 3 readings/second.

OVERRANGE INDICATION: "OL" displayed.

CREST FACTOR (ratio of peak value to rms value), AC FUNCTIONS: 3.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

COMMON MODE REJECTION RATIO (1kΩ unbalance): >120dB at DC, 50Hz, 60Hz ±0.1%. >60dB in AC volts.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable one year accuracy specification)/°C.

ENVIRONMENT: Operating: 0°–50°C; <80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°–50°C. **Storage:** –40° to +70°C.

WARM-UP: 1 hour to rated accuracy.

POWER: 105–125V or 210–250V (external switch selected), 90–110V available; 50–60Hz, 12VA. Removable power cord. Optional 5-7 hour battery pack, Model 1978.

DIMENSIONS, WEIGHT: 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (3 lbs., 14 oz.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, instruction manual.

5½-Digit DMM

- **3½- to 5½-digit resolution**
- **100nV, 100pA, 100μΩ, 0.01°C or °F sensitivities**
- **RTD temperature measurement**
- **100-reading data buffer**

IEEE-488

[illegible]

195A
System DMM with Temperature, Operator's Manual

195A/1950
System DMM with Temperature, DCA, TRMS ACV and ACA, Operator's Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

TEST LEADS

1681	Clip-On Test Lead Set
1683	Universal Test Lead Kit
1691	General Purpose Test Leads
5806	Kelvin Test Leads

PROBES/SHUNT

1301	Temperature Probe
8691	Pt RTD Connector Adapter Kit
8693	Pt RTD General Purpose Probe
8695	Pt RTD Surface Probe
8696	Pt RTD Air/Gas Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

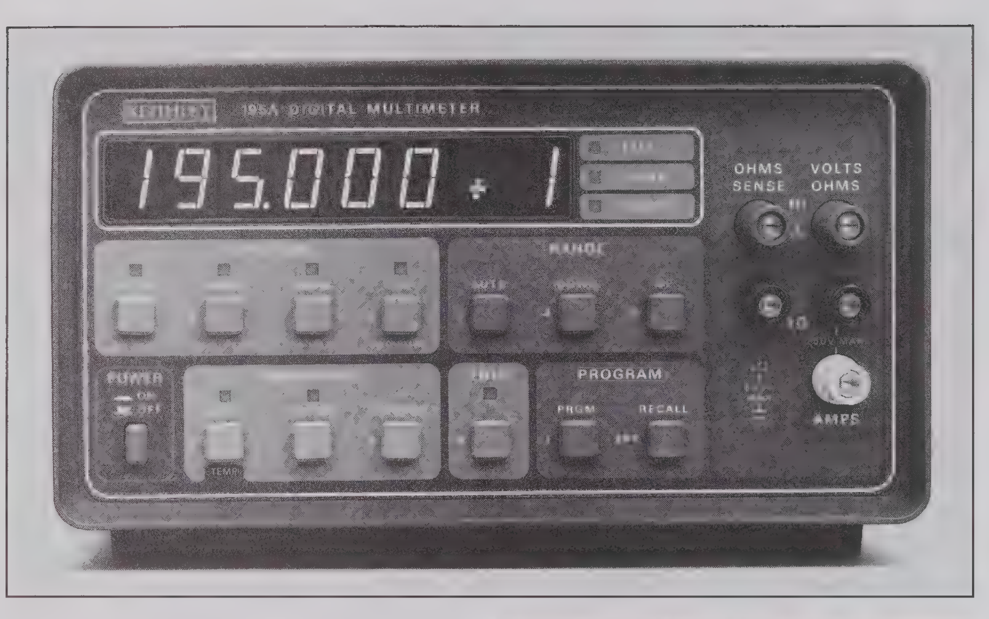
RACK MOUNT KITS

1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

OTHER

1951	Pt RTD Adapter

See page 163 for descriptions of all accessories.


KEITHLEY
195A DIGITAL MULTIMETER
195.000 + 1
RANGE
AUTO
POWER
ON
OFF
TEMP
PROGRAM
PRGM
RECALL
OHMS SENSE
VOLTS OHMS
AMPS

The Model 195A gives you Keithley sensitivity and versatility across six full functions. With the basic unit, you measure DC volts, automatic 2- or 4-wire ohms, and temperature (°C or °F). You can measure temperature accurately, using any 3- or 4-wire 100Ω RTD. Sensor current of <1mA rms minimizes self-heating error. With the Option 1950, you add TRMS AC volts, DC amps, and TRMS AC amps functions.

The Model 195A has outstanding sensitivity, including much more (100pA) in current than other 5½-digit DMMs. In addition, DC current can be measured on six ranges for maximum resolution.

The IEEE-488 bus interface is standard, and all functions are programmable. With front and rear inputs, External Trigger input, and Voltmeter (reading) Complete output, the 195A has all the capabilities to be a versatile measurement instrument in an IEEE-488 test system. Furthermore, the 100-reading buffer, combined with trigger control, enables the 195A to take automated measurements with or without a system controller.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Averaging, EOI, Trigger, Terminator, Filter, Delay, 100-Reading Storage, Calibration, Display, Multiplex Off, Status, Service Request, Self Test, Output Format.

[illegible]

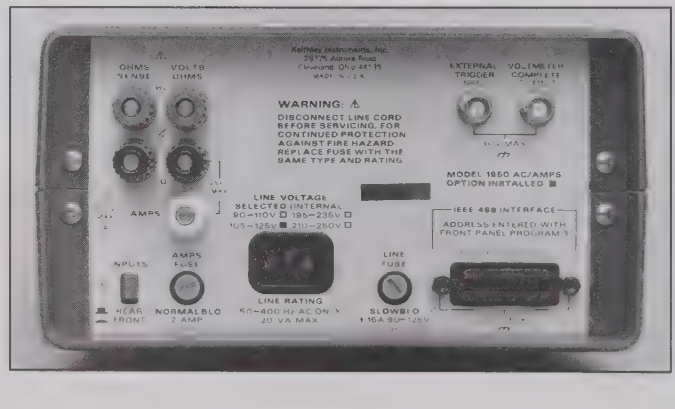
[illegible]	[illegible]	[illegible]	[illegible]
3½-Digit	3.3 ms	17 ms	76
4½-Digit	16.66 ms**	30 ms	36
5½-Digit	100 ms*	114 ms	9

*Readings/second. **20ms at 50Hz.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

PROGRAMMABLE SRQ MODES: SRQ On/Off. SRQ available on Reading Done, Overflow, Illegal DDC, Illegal DDC Option, Buffer Full, Buffer ½ Full, Self Test Failed, and Trigger Overrun.

STATUS: Transfers current instrument setup including model no. over the bus.


OHMS SENSE
VOLTS OHMS
AMPS
INPUTS
REAR
FRONT
AMPS FUSE
NORMAL BLO 2 AMP
WARNING:
DISCONNECT LINE CORD BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD REPLACE FUSE WITH THE SAME TYPE AND RATING
LINE VOLTAGE SELECTED (INTERNAL)
90–110V
195–235V
105–125V
210–250V
LINE RATING
50–400 Hz AC ONLY
20 VA MAX
LINE FUSE
SLOW BLO
EXTERNAL TRIGGER
VOLTMETER COMPLETE
MODEL 1950 AC/AMPS OPTION INSTALLED
IEEE 488 INTERFACE
ADDRESS ENTERED WITH FRONT PANEL PROGRAM 3

5½-Digit DMM

195A

TEMPERATURE

SPAN	RESOLUTION	ACCURACY	TEMPERATURE COEFFICIENT
–200.00° to +230.00°C	0.01°C	0.03 + 10	0.003 + 0.4
+230.00° to +630.00°C	0.01°C	0.03 + 40	0.003 + 4
–328.00° to +446.00°F	0.01°F	0.03 + 18	0.003 + 0.7
+446.00° to 1100.00°F	0.01°F	0.03 + 72	0.003 + 7

*Autorange mode, excluding probe errors.

RTD TYPE: 100Ω platinum; DIN 43 760 or IPTS-68, programmable alpha and delta, 3- or 4-wire.

MAXIMUM LEAD RESISTANCE (each lead): 4-wire: 25Ω; 3-wire: 15Ω.

SENSOR CURRENT: 1.0mA maximum, rms.

BENCH READING RATE: 1.2 reading/second.

MAXIMUM COMMON MODE VOLTAGE: 500V (42V with Model 1951 connected).

COMMON MODE REJECTION: <0.005°C/V at DC, 50Hz and 60Hz (100Ω unbalance, LO driven).

MAXIMUM ALLOWABLE INPUT: 360V peak, 250V rms.

GENERAL

DISPLAY: Six 0.5 in. LED digits with decimal point, exponent, and polarity. Function and IEEE-488 bus status also displayed.

RANGING: Manual or fast autoranging (150ms/range change on DC volts).

ISOLATION: Input LO to IEEE LO or power line ground: 500V max., 5 × 10⁵V•Hz; >10⁹Ω paralleled by 300pF.

WARM-UP: 1 hour to rated accuracy.

OPERATING ENVIRONMENT: 0°–50°C, 0% to 80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: –25° to 65°C.

POWER: 105–125V or 210–250V (internal switch selected), 50Hz to 400Hz, 24VA maximum. 90–110V & 180–220V versions available upon request.

CONNECTORS: Analog: Switch selectable front or rear, 5-way gold plated binding posts. **Digital:** Trigger input and Voltmeter Complete output on rear panel: BNCs.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.2kg (7 lbs.).

FRONT PANEL PROGRAMS

NO.	NAME	DESCRIPTION
0	CLEAR	Cancels program mode.
1	NON-VOLATILE RAM STORAGE	Stores programs 3, 4, 5, and 8 data in NVRAM.
2	MULTIPLEX	Defeats input amplifier multiplexing.
3	IEEE BUS MODE	ADDRESSABLE and TALK ONLY entry.
4	LINE FREQUENCY	Selects 50Hz or 60Hz operation.
5	CALIBRATION	Performs digital calibration.
6	EXTENDED PROGRAMS	Enables entry to optional expansion programs.
7	DATA LOGGER	Allows 100-reading storage at 9 programmable rates; also stores highest, lowest, and average reading.
8	DIAGNOSTICS	Troubleshooting aid and self-test.
9	TRIGGER	Enables front panel or external triggering.

RANGE	RESOLUTION	INPUT RESISTANCE			
20 mV	100 nV	>1 GΩ	0.01 + 40	0.025 + 40	0.003 + 2
200 mV	1 µV	>1 GΩ	0.01 + 6	0.025 + 6	0.003 + 0.5
2 V	10 µV	>1 GΩ	0.01 + 8	0.025 + 8	0.003 + 0.5
20 V	100 µV	10 MΩ	0.01 + 6	0.025 + 6	0.003 + 0.5
200 V	1 mV	10 MΩ	0.01 + 8	0.025 + 8	0.003 + 0.5
1000 V	10 mV	10 MΩ	0.01 + 6	0.025 + 6	0.003 + 0.5

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20mV range after zeroing).

NMRR: >60dB at 50 or 60Hz. **CMRR:** >120dB at DC and 50 or 60Hz (with 1kΩ in either lead).

MAXIMUM ALLOWABLE INPUT: 1000V peak. **BENCH READING RATE:** 5 readings/second.

20 Ω	100 µΩ	–2 mA	–2 V	0.015 + 25	0.025 + 25	0.003 + 2
200 Ω	1 mΩ	–2 mA	–2 V	0.015 + 7	0.025 + 7	0.003 + 0.5
2 kΩ	10 mΩ	–2 mA	–2 V	0.015 + 5	0.022 + 5	0.003 + 0.5
20 kΩ	100 mΩ	–20 µA	–2 V	0.015 + 7	0.025 + 7	0.003 + 0.5
200 kΩ	1 Ω	–20 µA	–2 V	0.015 + 5	0.022 + 5	0.003 + 0.5
2MΩ	10 Ω	–200 nA	–2 V	0.03 + 7	0.050 + 7	0.015 + 1
20MΩ	100 Ω	–200 nA	–2 V	0.06 + 5	0.100 + 5	0.025 + 1

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20Ω range after zeroing).

200 mV **	1 µV	0.8 + 200	0.3 + 200	0.7 + 200	2.0 + 300
2 V	10 µV	0.8 + 200	0.3 + 200	0.7 + 200	2.0 + 250
20 V	100 µV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250
200 V	1 mV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250
700 V	10 mV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250

*In 4½-digit mode, divide count error by 10. **Above 1mV.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification)/°C.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

INPUT IMPEDANCE: 2MΩ shunted by <75pF.

MAXIMUM ALLOWABLE INPUT: 1000V peak, 10⁷V•Hz. **BENCH READING RATE:** 3 readings/s.

CMRR: >60dB at DC, 50 or 60Hz (with 1kΩ in either lead). **BANDWIDTH:** –3dB at 250kHz typical.

20 µA	100 pA	0.14 + 40**	0.01 + 2	0.03 V
200 µA	1 nA	0.09 + 10	0.01 + 0.5	0.25 V
2 mA	10 nA	0.09 + 10	0.01 + 0.5	0.25 V
20 mA	100 nA	0.09 + 10	0.01 + 0.5	0.25 V
200 mA	1 µA	0.09 + 10	0.01 + 0.5	0.28 V
2 A	10 µA	0.09 + 10	0.01 + 0.5	1 V

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20mA range after zeroing).

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

BENCH READING RATE: 5 readings/second.

200 µA	1 nA	0.6 + 250	0.04 + 10	0.25 V
2 mA	10 nA	0.6 + 250	0.04 + 10	0.25 V
20 mA	100 nA	0.6 + 250	0.04 + 10	0.25 V
200 mA	1 µA	0.6 + 250	0.04 + 10	0.28 V
2 A	10 µA	0.6 + 250	0.04 + 10	1 V

*Above 0.5% of range. In 4½-digit mode, divide count error by 10.

RESPONSE: True root mean square, AC coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible. **BENCH READING RATE:** 3/second.

6½-Digit DMM

- 3½- to 6½-digit resolution
- Up to 1000 rdg./second
- Non-volatile reading memory
- Nine functions
- RTD and thermocouple temperature measurements

IEEE-488

[illegible]

193A
System DMM (3½- to 6½-Digit) with Instruction Manual

193A/1930
System DMM with TRMS AC Volts and Instruction Manual

193A/1931
System DMM with Current Option and Instruction Manual

193A/30/31
System DMM w/TRMS AC Volts & Current Option and Instruction Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

TEST LEADS
1681 Clip-On Test Lead Set
1751 Safety Test Leads
1754 Safety Universal Test Lead Kit
5806 Kelvin Test Leads

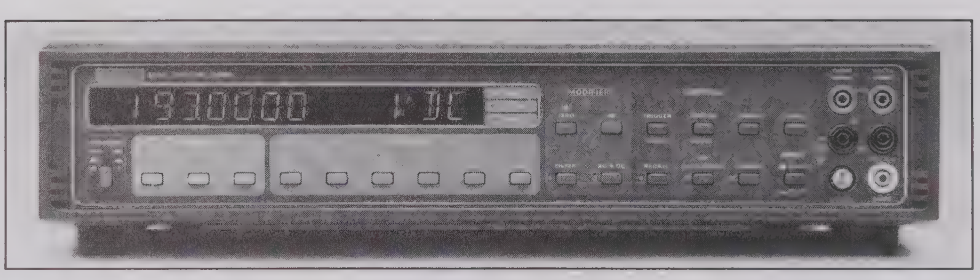
PROBES/SHUNT
1301 Temperature Probe
1600A High Voltage Probe
1651 50A Current Shunt
1682A RF Probe
1685 Clamp-On Current Probe

CABLES
7007-1 Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2 Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3 IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6 IEEE-488 Digital Cable, 1.8m (6 ft.)

RACK MOUNT KITS
1938 Single Fixed Rack Mount Kit
1939 Dual Fixed Rack Mount Kit

OTHER
1930 TRMS ACV Option
1931 Current Option

See page 163 for descriptions of all accessories.



The Model 193A System DMM combines high speed, 9 functions, and superior performance into one of the best values in instrumentation.

9 Measurement Functions

[illegible]	[illegible]	[illegible]	[illegible]
1. DC Voltage	•		
2. Resistance	•		
3. dBV	•		
4. AC Voltage		•	
5. DC Current			•
6. AC Current		•	•
7. Temperature (RTD)	•		
8. Temperature (Thermocouple)	•		
9. Low Freq. AC	•		

Speed

To maximize system throughput or monitor changes and trends, reading rates up to 1000/second are achievable.

Data Buffer

Up to 500 locations of non-volatile memory are available for data logging. Data can be recalled at any time without affecting the memory. HI, LO, and AVERAGE values are also available.

Trigger

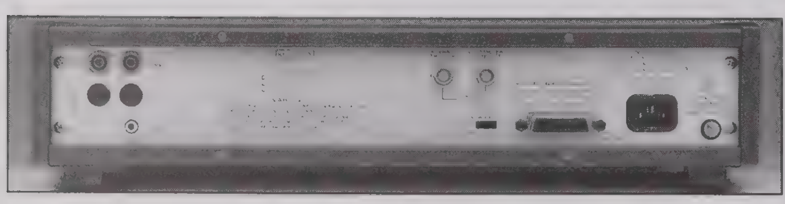
The 193A can be triggered from the IEEE-488 bus, front panel, or through the EXTERNAL TRIGGER input on the rear panel. A separate trigger delay time can be programmed over the bus. VOLTMETER COMPLETE signals the system that the data have been acquired.

Zero

The ZERO function subtracts any on-scale display reading from all subsequent measurements for relative readings or to compensate for unwanted background signals.

Filter

The FILTER control enables and disables a programmable weighted average digital filter to reduce noise encountered in the signal.



Digital Calibration

A recessed switch on the rear panel locks the calibration and can be covered for security.

Front/Rear Inputs

All inputs, including current, are available on front and rear panels. A front panel switch selects the appropriate inputs; its position is sensed and reported over the IEEE-488 bus.

Non-Volatile TRANSLATOR

A Keithley exclusive, the sophisticated TRANSLATOR software offers extraordinary programming flexibility. Define your own words to the 193A, and it will learn and respond. Advantages include:

- Using terminology with specific meaning to your application in place of cryptic mnemonics:

Send DCV instead of F0.

- Abbreviate frequent setups to reduce IEEE-488 bus transfers:

Send TEST1 instead of F3R1T2S0Z1U0M2P1X.

- Translate Keithley commands to emulate functions of other units:

Send RA to program autorange in place of R0.

Thus, the use of the TRANSLATOR can make programs more readable, reduce bus transfer times for instruction strings, and enable the 193A to upgrade a system without major changes to existing software. TRANSLATOR commands are retained in non-volatile memory.

LOW FREQ. [illegible] AC VOLTS

RANGES: 200mV to 700V.

ACCURACY (1 Year), ±(%rdg + counts): ±(2% rdg + 3 counts).

RESPONSE: True root mean square, AC + DC.

BANDWIDTH: 0.1 to 10Hz.

ADDITIONAL FUNCTIONS

[illegible]	[illegible]	[illegible]	[illegible]
ACV dB	1 V	–34 to 57 dBV	0.01 dBV
ACA dB	1 mA	–54 to 66 dB	0.01 dB
Thermocouple Temperature*	Ext.	–100° to 1372°C	0.1°C (Types J, K, T, E)
RTD Temperature	DIN 43760 or IPTS-68	–100° to 630°C	0.01°C

*Over IEEE-488 bus only.

6½-Digit DMM

193A

TRMS AC AMPS [illegible] (5½-Digit) RANGE	RESOLUTION	ACCURACY ±(%rdg+counts) 1 Year, 18°–28°C [illegible]–10kHz	MAXIMUM VOLTAGE BURDEN
200 µA	1 nA	0.6 + 300	0.25 V
2 mA	10 nA	0.6 + 300	0.25 V
20 mA	100 nA	0.6 + 300	0.25 V
200 mA	1 µA	0.6 + 300	0.28 V
2 A	10 µA	0.6 + 300	2 V

[1]For sinewave inputs >2000 counts.

RESPONSE: True root mean square, AC or AC + DC.

CREST FACTOR: Rated accuracy to 3. Specified for pulse width >1ms, peak current ≤ 1.36 × range. AC + DC: Add 60 counts to specified accuracy.

SETTLING TIME: 0.5 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 2A, 250V.

OVERLOAD PROTECTION: 2A fuse (250V) accessible from front panel.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C), ±(%rdg + counts): 0.04 + 10.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Rdg. Storage, Calibration, Display, MUX, Status, Service Request, Self Test, Output Format, Reference Junction, TRANSLATOR.

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 2,199,999 counts in 6½-digit mode, except 1,000,000 on 1000V DC range and 700,000 on 700V AC range.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5 × 10^5 max. V•Hz product. >10^9Ω paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 rdg./s (2/s on 20MΩ and 200MΩ ranges).

FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

ENVIRONMENT: Operating: 0°–50°C, 0%-80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°–50°C (0%–60% RH up to 28°C on 200MΩ range). **Storage:** –25° to +65°C.

POWER: 105–125V or 210–250V, internal switch selected, 50Hz or 60Hz, 40VA max. 90–110V and 180–220V versions available upon request.

DIMENSIONS, WEIGHT: 89mm high × 438mm wide × 441mm deep (3½ in. × 17¼ in. × 17⅜ in.). Net weight 7.4kg (15 lbs.).

DC VOLTS (6½-Digit) RANGE	RESOLUTION	ACCURACY ±(%rdg+counts)[1] 24 Hr.[2]	90 Days	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°–18°C & 28°–50°C
200 mV	100 nV	0.0020 + 20[3]	0.005 + 20[3]	0.0006 + 10
2 V	1 µV	0.0013 + 10	0.003 + 20	0.0003 + 1
20 V	10 µV	0.0015 + 10	0.006 + 10	0.0007 + 1
200 V	100 µV	0.0025 + 10	0.006 + 10	0.0007 + 1
1000 V	1 mV	0.004 + 10	0.007 + 10	0.0007 + 1

[1]For 5½-digit accuracy, divide count error by 10.

[2]Relative to calibration standards.

[3]When properly zeroed.

CMRR: >120dB at DC, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

MAXIMUM ALLOWABLE INPUT: 1000V peak.

INPUT RESISTANCE: >1GΩ except 10MΩ on 20V range and above.

TRMS AC VOLTS (Option [illegible]) (5½-Digit) RANGE	RESOLUTION	ACCURACY ±(%rdg+counts)[1] 1 Year, 18°–28°C 20Hz–50Hz	50Hz–10kHz	10kHz–20kHz	20kHz–100kHz
2 V	10 µV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
20 V	100 µV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
200 V	1 mV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
700 V	10 mV	1 + 100	0.35 + 100	0.5 + 300	1 + 500

[1]Multiply digit error by 10 for 6½-digit accuracy.

[2]For sinewave inputs >2,000 counts.

[3]For sinewave inputs >20,000 counts.

RESPONSE: True root mean square, AC or AC+DC.

CREST FACTOR: Rated accuracy to 3. Specified for pulse widths >10ms, peak voltage ±1.36% range.

AC+DC: Add 60 counts to specified accuracy.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

3dB BANDWIDTH: 500kHz typical.

MAXIMUM ALLOWABLE INPUT: 1000V peak AC + DC, 2 × 10^7V•Hz.

SETTLING TIME: 0.5 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy spec.)/°C below 50kHz, ±(0.2×) for 50kHz–100kHz.

OHMS (6½-Digit) RANGE	RESOLUTION	CURRENT THROUGH UNKNOWN	ACCURACY ±(%rdg+counts) 24 Hr.	90 Days	1 Year
200 Ω	100 µΩ	1 mA	0.0025 + 20	0.007 + 20	0.010 + 20
2 kΩ	1 mΩ	1 mA	0.0025 + 20	0.005 + 20	0.007 + 20
20 kΩ	10 mΩ	100 µA	0.0025 + 20	0.005 + 20	0.007 + 20
200 kΩ	100 mΩ	10 µA	0.0035 + 20	0.007 + 20	0.010 + 20
2 MΩ	1 Ω	1 µA	0.005 + 20	0.010 + 20	0.010 + 20
20 MΩ	10 Ω	100 nA	0.04 + 20	0.070 + 20	0.070 + 20
200 MΩ	1 kΩ	100 nA	3.2 + 2	3.2 + 2	3.2 + 2

CONFIGURATION: Automatic 2- or 4-wire.

MAX. ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

MAXIMUM OPEN CIRCUIT VOLTAGE: –7V.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 200Ω-20kΩ ranges, at 23°C ±1°C.

DC AMPS (Option [illegible]) RANGE	RESOLUTION	ACCURACY [illegible]	MAXIMUM VOLTAGE BURDEN
200 µA	1 nA	0.09 + 10	0.25 V
2 mA	10 nA	0.09 + 10	0.25 V
20 mA	100 nA	0.09 + 10	0.25 V
200 mA	1 µA	0.09 + 10	0.28 V
2 A	10 µA	0.09 + 10	1 V

MAXIMUM ALLOWABLE INPUT: 2A, 250V.

OVERLOAD PROTECTION: 2A fuse (250V), accessible from front panel.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C), ±(%rdg + counts)/°C: ±(0.001 + 0.5)/°C.

194A

High Resolution Digitizer

- **16-bit (4½-digit) resolution at 100k samples/second**
- **Up to 1,000,000 samples/ second**
- **64k bytes memory/ channel**
- **Two independent, fully programmable channels**

IEEE-488

[illegible]

194A
High Resolution Digitizer with Instruction Manual

194A/1944A
Dual Channel High Resolution Digitizer with Instruction Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CABLES

1942	External Sample Trigger Cable
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
7754-3	BNC to Alligator Cable, 0.9m (3 ft.)
7755	50Ω Feed-Through Terminator

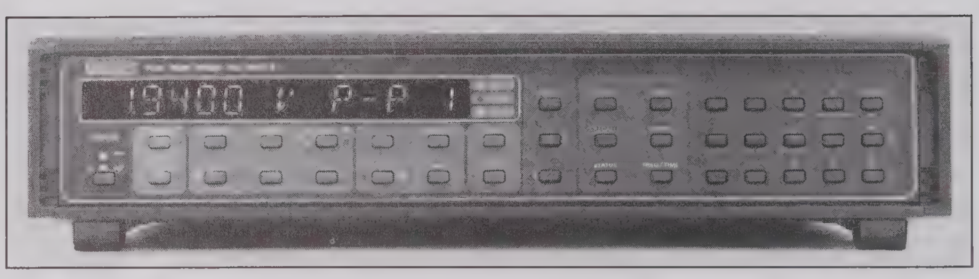
RACK MOUNT KITS

1938	Single Fixed Rack Mount Kit
1939	Single Slide Rack Mount Kit

OTHER

1944A	Second Channel

See page 163 for descriptions of all accessories.



The Model 194A high resolution digitizer can acquire waveforms with 16 bits of resolution at sampling rates up to 100k samples/second. Eight-bit resolution can be obtained up to rates of 1M samples/second. With the Model 1944A Channel 2 option, two waveforms or two externally-triggered sets of samples can be taken simultaneously. In addition to waveform acquisition, the Model 194A also provides waveform analysis capability with eight built-in computation functions.

The 194A is a fully programmable IEEE-488 interfaceable instrument. The interface enables use in an automated system, where its full power can be realized.

High Resolution Digitizer

At sampling rates up to 100kHz, the 194A provides 16-bit (4½-digit) resolution. Thus the 194A is capable of detecting changes as small as 1 part in 65,536. This is far greater resolution than is provided by most other digitizing instruments, and enables the 194A to extract more information from a waveform. The 194A also accepts a wider range of input signals: it can detect as low as 10μV, and is designed to digitize up to 200V. Because its input is isolated, input signals need not be referenced to ground.

When greater speed is more important than high resolution, the 194A can sample at rates between 100kHz and 1MHz with 8-bit resolution. Unlike some digitizers, it is not limited to a fixed set of rate options: Any sampling time interval from 1.0μs to 1.0s can be programmed, and resolution is 0.1μs over the complete range of time intervals.

Extensive Memory

A total of 64k bytes of memory is available for sample storage. In 16-bit resolution mode, the 194A can store 32k samples; with 8-bit resolution, storage capacity increases to 64k samples. This is 16 times greater than the available memory in many other digitizing instruments.

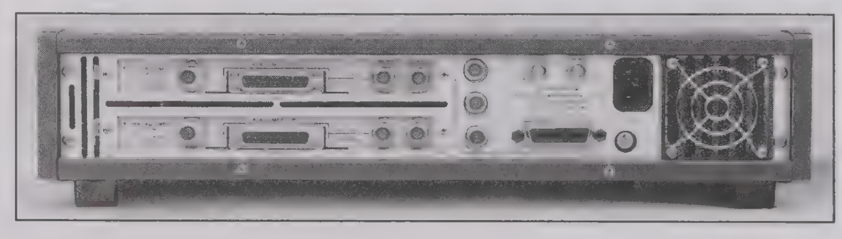
The 194A can store data prior to a trigger event (pre-trigger) or delay the onset of data storage for a fixed time after a trigger event (post-trigger). Pre-triggering enables the investigation of phenomena that occurred prior to an event being studied; post-triggering avoids the collecting of an unwanted segment of information, such as a switching-related transient, following a trigger event.

Two Independent Channels

Two waveforms or two sets of samples can be acquired simultaneously or in time synchronization with the addition of the optional Model 1944A Channel 2. With the second channel installed, the Model 194A becomes two entirely independent waveform acquisition channels, each with 64k of memory.

Measurement Triggers

For waveform acquisition, there is a choice of five trigger sources which are independently programmed for each channel: 1.) an input waveform at any level or slope; 2.) an external TTL control signal; 3.) an IEEE-488 command; 4.) the other channel; and 5.) manual, push-button trigger. Once triggered, the 194A digitizes at the programmed sampling rate.



External Sample Trigger

When high speed measurements synchronized to external events must be acquired, the Model 194A offers the fastest sample trigger rate available: 1MHz. For high throughput in component test systems or for data acquisition at varying sample intervals, the 194A can respond to external sample trigger pulses generated at intervals as short as 1µs. Examples of applications where fast external triggering is necessary include dynamic testing of A/D and D/A converter operation, in which sample acquisition must be synchronized to input source transitions, and measurements synchronized to non-constant mechanical rotations from a motor drive.

Waveform Analysis

The 194A directly computes and displays waveform parameters. It supplies a waveform's positive and negative peaks, the peak-peak, an average, or an RMS value. The RMS computation is accurate for any type of waveform. Unlike conventional DMMs, which convert an AC signal to a DC signal with a non-linear circuit, the 194A digitizes directly and mathematically computes the RMS. The RMS computation is not affected by non-linear circuit effects, and is not limited to signals of specific crest factors, as is a DMM.

The INTEGRATE function can be used to convert an acceleration waveform into a velocity. For statistical analysis, the STANDARD DEVIATION of a set of samples can be taken. With two channels, RATIO and DIFFERENCE functions can provide comparison information on two waveforms.

For test set-up and troubleshooting, or for hard copy output without a computer, analog outputs can transmit a stored waveform to an oscilloscope, a CRT monitor, a chart recorder, or an analog X-Y recorder.

High Speed IEEE-488 Bus Performance

The 194A is optimized to handle the large quantity of data that can be stored. In binary format, data can be transmitted over the IEEE-488 bus at 90k bytes/second. At this speed, the 194A can transfer the total contents of the 64k memory to a computer in under 1 second. Furthermore, each channel has a real time output port, so that data can be transferred as it is digitized. At the fastest sampling rate, samples can be output over the real time output port at 1M samples/second.

TRANSLATOR

Our exclusive TRANSLATOR software can reduce IEEE-488 bus traffic by converting long command strings into short, understandable mnemonics. For example, instead of having to transfer a long command string like:

F2R1S0/10E-6N1/250E-1I1P0X

you can send: TEST1

Your code becomes more readable and, in this case, only 5 characters must be transferred over the bus as opposed to 26.

MEASUREMENT TRIGGER

MEASUREMENT TRIGGER: Initiates acquisition of a set of samples.

DELAY:

Pre-Trigger: –32k<n<–1, 16-bit mode; –64k<n<–1, 8-bit mode. |n| samples are stored prior to measurement trigger.

Post-Trigger: $1<n<1 \times 10^7$. Storage begins "n" samples after measurement trigger.

SOURCE:	**Description**
Input Signal	Slope: + or –. Level: Selectable over input voltage range and resolution.
External:	Negative TTL edge, rear panel BNC.
Front Panel:	Manual pushbutton.
IEEE-488 Interface:	16 programmable trigger modes.
Other Channel:	Internally generated.

MATH FUNCTIONS

AVERAGE: $\frac{\sum_{i=0}^{n-1} V_i}{n} = V_{avg}$

PEAK TO PEAK: Difference between maximum and minimum values of samples.

PLUS PEAK: Maximum value of samples.

MINUS PEAK: Minimum value of samples.

STANDARD DEVIATION: $\frac{\sum_{i=0}^{n-1} (V_i - V_{avg})^2}{n}$

TRUE ROOT MEAN SQUARE: $\frac{\sum_{i=0}^{n-1} (V_i)^2}{n}$

INTEGRAL: $(\frac{1}{2} V_0 + \frac{1}{2} V_{n-1} + \sum_{i=1}^{n-2} V_i)\, t_s.$

DIFFERENCE: Channel 1 – Channel 2.

RATIO: Channel 1 / Channel 2.

NOTE: V_i: Voltage of sample i. **n:** Total number of samples.

i: Location of individual sample. t_s: Sample interval.

194A High Resolution Digitizer

DC CHARACTERISTICS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
±320 mV	10 µV	0.030% + 200 µV	2.56 mV	0.42% + 2.56 mV
± 3.2 V	100 µV	0.025% + 2 mV	25.6 mV	0.42% + 25.6 mV
± 32 V	1 mV	0.035% + 20 mV	256 mV	0.42% + 256 mV
±200 V	10 mV	0.035% + 200 mV	2.56 V	0.42% + 2.56 V

*After pushbutton or bus zeroing, and using average function (10,000 samples, 10µs sample rate).

INPUT IMPEDANCE: 1.1MΩ (1.0MΩ on 200V range) shunted by <70pF.

MAXIMUM ALLOWABLE INPUT: 250V peak, 10^6V•Hz.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, 42V peak, 5×10^5 V•Hz.

COMMON MODE REJECTION RATIO: >60dB at DC to 1kHz, 1kΩ unbalance.

DIFFERENTIAL NONLINEARITY: 16-Bit: ≤2 LSB. **8 Bit:** ≤0.5 LSB.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): < ±(0.1 × applicable accuracy specification)/°C.

[illegible]

SAMPLE TRIGGER: Initiates each A/D conversion.

EXTERNAL SAMPLE TRIGGER INPUT: Rising edge. TTL compatible. DB-25 connector.

	[illegible]	[illegible]	[illegible]	[illegible]
SAMPLE RATE				
Maximum	100 kHz	1 MHz	100 kHz	1 MHz
SAMPLE INTERVAL				
Minimum	10 µs	1 µs	10 µs	1 µs
Maximum	1 s	1 s	No limit	No limit
Resolution	100 ns	100 ns	—	—
Jitter (typical)	±0.4 ns	±2 ns	±2 ns	±2 ns
TIMEBASE ACCURACY				
	±0.02%	±0.02%	±0.02%	±0.02%
NUMBER OF SAMPLES				
Minimum	1	1	1	1
Maximum	32k	64k	32k	64k

SIGNAL/NOISE RATIO (sinewave curve fit): 50dB for full range 100kHz sine input; 72dB typical at 10kHz.

SLEW RATE: 13V/µs minimum.

SETTLING TIME: 1 µs to 1% of final value.

CHANNEL CROSSTALK: <60dB at 500kHz.

INPUT COUPLING: AC, DC, ground.

FREQUENCY RESPONSE (Filter Off):

0.2 dB	1 dB	3 dB
DC (15 Hz)–20 kHz	DC (5 Hz)–200 kHz	DC (2 Hz)–750 kHz

( ) Indicates AC coupled performance.

LOW PASS FILTER: 50kHz, 500kHz, single pole.

CHANNEL 2 (Option 1944A)

Permits synchronous or asynchronous sampling of data. Specifications are identical to those of Channel 1. All Channel 2 measurement parameters are independently selectable and can be made simultaneously.

REAL TIME (DMA) OUTPUT

FORMAT: Binary, 16-bit or 8-bit.

RATE: Same as Sample Rate.

CONTROL LINES: End of Sample, Overrun, High Byte, Low Byte.

ANALOG OUTPUT

MODES	OUTPUTS USED
CRT	x, y, z (blanking)
Oscilloscope	y, z (trigger)
Slow Plot	x, y, z (pen up/down)
Strip Chart	y

X OUTPUT: 0–10V full scale, 2.44mV resolution.

Y OUTPUT: 0–10V full scale, 2.44mV resolution.

Z OUTPUT: 0V, 5V or 15V.

ZOOM MAGNIFICATION: 0.1:1 to 1000:1.

PAN: Across entire memory.

FRONT PANEL PROGRAMS

0	IEEE ADDRESS: Set IEEE-488 address.
1	SELF TEST: Performs internal RAM and ROM check.
2	DIGITAL CALIBRATION: Executes calibration procedure.
3	CALIBRATION STORAGE: Stores calibration constants in NVRAM.
4	X OUTPUT FULL SCALE: Sets full scale X output voltage.
5	Y OUTPUT FULL SCALE: Sets full scale Y output voltage.
6	Z OUTPUT BLANKING LEVEL: Sets high or low blanking level.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD, MLA, MTA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Math Functions, Zero, Delay, Sample Rate, Number of Samples, Trigger, Calibration, Output Format, Self Test, Display, Status, Service Request, Storage, Filter, Terminator, Input Coupling, Buffer Size, Channel, Save and Recall Setups, Front Panel Programs 1-6, Key Sequence, Slope, Analog Outputs, EOI.

BINARY TRANSFER RATE: 90k bytes/second.

GENERAL

DISPLAY: 14-digit alphanumeric LED display; function, bus status also displayed.

RANGING: Manual or autoranging.

WARM-UP: One hour to rated accuracy.

OPERATING ENVIRONMENT: 0° to 50°C, 0% to 80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: –25° to 65°C.

POWER: 105–125V or 210–250V (internal switch selectable), 50Hz or 60Hz, 120VA maximum. 90–110V and 180–220V version available.

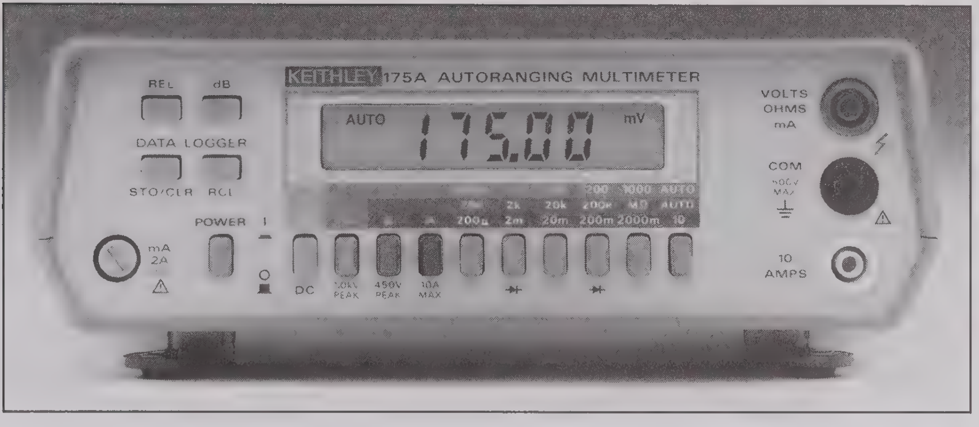
CONNECTORS: All I/O connectors are BNC except Real Time Output (DB-25) and IEEE-488 connectors.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in. × 17⅛ in. × 17⅝ in.). Net weight 9.1kg (20 lbs.), Dual Channel.

4½-Digit DMM

175A

- IEEE-488 interface option
- 100-point data logger
- Digital calibration
- TRMS AC measurement
- Backlit display



The Keithley Model 175A is a 4½-digit LCD bench/portable DMM with 0.03% basic DCV accuracy. It offers extended measurement capabilities including a 10A current range, 100kHz bandwidth, and resistance measurements from 10mΩ to 200MΩ. Annunciators provide function, range, and feature indication.

With the Model 175A, choose either manual or autoranging. Fast autoranging is available on DC volts, ohms, AC volts, and dB.

Data Logging

The Model 175A's 100-point data logger is capable of storing data at six selectable rates from three readings per second to one every hour. Data can be recalled from the front panel. This feature enables collection of response curve data and monitoring of drifts or rates of change without the need for a printer.

The Min/Max hold feature holds both lowest and highest readings over a selected period of time.

Relative Measurements

The dB function makes the Model 175A suitable for audio and communications applications.

Direct dB readings are given throughout a dynamic range from –98 to +62dB, with 0.01dB resolution above 10mV. The 100kHz bandwidth covers well past the audio range. The optional RF probe extends the bandwidth to 250MHz.

The relative reference allows nulling out circuit voltage offsets or lead resistances. By nulling out power supply voltages or circuit outputs, drifts or changes can be displayed. Combined with the dB function, it can be used to make fast gain-stage measurements.

Digital Calibration

With the Model 175A's digital calibration, all calibration factors are stored in non-volatile memory, allowing calibration to be done electronically without manual adjustments. The IEEE-488 interface option offers range programmability on volts and ohms, TALK/LISTEN capability, trigger, SRQ, and other commands. Combined with the digital calibration feature, calibration can be performed on the bus in as little as two minutes.

IEEE-488

[illegible]

All include Instruction Manual and Model 1751 Safety Test Leads.

175A
Autoranging DMM

175A/1753A
Autoranging DMM with IEEE-488 Interface

175A/1758
Autoranging DMM with Rechargeable Battery Pack

175A/53/58
Autoranging DMM with IEEE-488 Interface and Rechargeable Battery Pack

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

TEST LEADS	
1681	Clip-On Test Lead Set
1751	Safety Test Leads
1754	Safety Universal Test Lead Kit
CABLES	
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
PROBES/SHUNT	
1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe
OUTPUTS	
1753A	IEEE-488 Interface
POWER	
1758	Rechargeable Battery Pack
RACK MOUNT KITS	
1010	Single Fixed Rack Mount Kit
1017	Dual Fixed Rack Mount Kit
CARRYING CASES	
1684	Hard Shell Carrying Case
1686	Vinyl Carrying Case
OTHER	
1759	Spare Parts Kit

See page 163 for descriptions of all accessories.

175A 4½-Digit DMM

DC VOLTS RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY (1 Year) 18°–28°C ±(%rdg + counts)
200 mV	10 μV	>1 GΩ *	0.03 + 2
2 V	100 μV	>1 GΩ *	0.03 + 1
20 V	1 mV	11 MΩ	0.03 + 1
200 V	10 mV	10 MΩ	0.03 + 1
1000 V	100 mV	10 MΩ	0.03 + 1

*With all function buttons in the out position.

NORMAL MODE REJECTION RATIO: >60dB at 50Hz, 60Hz ±0.15%.

MAXIMUM ALLOWABLE INPUT: 1000V DC or peak AC (<10s per minute on 200mV and 2V ranges; 300V rms continuous).

SETTLING TIME: 1s to within 1 count of final reading on range.

dB MODE (ref: 600Ω): Accuracy: ±(0.02dB + 1 count) (above –78dBm). **Resolution:** 0.01dB above 5% of range.

TRMS AC VOLTS RANGE	[illegible]	[illegible]	[illegible]–10kHz	10kHz–20kHz	[illegible]	[illegible]
2V–750V	1 + 20	0.5 + 20	1 + 40	2.5 + 75	5 + 200	
200 mV	1 + 20	0.5 + 20	1.5 + 40	8 + 75	—	

[illegible] RANGE	INPUT	[illegible]	[illegible]–20kHz	[illegible]	[illegible]
2V–750V	200 mV to 750 V (–12 to +59.8dBm)	0.2	0.26	0.56	1.2
200 mV	20 mV to 200 mV (–32 to –12 dBm)	0.2	0.3	1	—
	2 mV to 20 mV (–52 to –32 dBm)	2	3	—	—
	1 mV to 2 mV (–58 to –52 dBm)	2**	—	—	—

Resolution: 0.01dB above 5% of range.

*Above 1800 counts.
**Up to 1kHz.

MAXIMUM ALLOWABLE INPUT: 750V rms, 1000V peak (<10 seconds per minute on 200mV range; 300V rms continuous). 10^7V•Hz maximum.

3dB BANDWIDTH: 300kHz typical.

INPUT IMPEDANCE: 10MΩ paralleled by <75pF on 20V, 200V, and 1000V ranges. 11MΩ on 200mV and 2V ranges. Capacitively coupled.

SETTLING TIME: 2 seconds to within 15 counts of final reading on range.

TRMS AC AMPS RANGE	MAXIMUM BURDEN	[illegible]	50Hz–10kHz	[illegible]
200μA–20mA	0.3 V	1 + 20	0.8 + 20	2 + 50
200 mA	0.3 V	1 + 20	0.8 + 20	—
2000 mA	0.8 V	1 + 20	0.8 + 20	—
10 A	0.3 V	1.5 + 20**	1 + 20**	—

*Above 1800 counts. **1kHz max. Above 5A derate 0.15% rdg/amp for self-heating.

SETTLING TIME: 2 seconds to within 15 counts of final reading.

IEEE-488 BUS IMPLEMENTATION [illegible]

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL2, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, REL, dB, EOI, Trigger, Calibration, SRQ, Status, Output Format, Terminator.

OHMS RANGE	RESOLUTION	ACCURACY (1 Year) 18°–28°C ±(%rdg + counts)	MAX VOLTAGE ACROSS UNKNOWN [illegible]
200 Ω	10 mΩ	0.05 + 2*	0.2 V
2 kΩ ▶	100 mΩ	0.05 + 1	2.0 V
20 kΩ	1 Ω	0.05 + 2	0.2 V
200 kΩ ▶	10 Ω	0.05 + 1	2.0 V
2MΩ**	100 Ω	0.05 + 2	0.2 V
20MΩ**	1 kΩ	0.2 + 1	2.0 V
200MΩ**	100 kΩ	2.0 + 1	2.0 V

*When properly zeroed.
**Appropriate range selected automatically.

MAXIMUM ALLOWABLE INPUT: 450V DC or peak AC.

OPEN-CIRCUIT VOLTAGE: +5V.

DIODE TEST: Display reads junction voltage up to 2V. Test current: 0.7mA nominal.

SETTLING TIME: 2 seconds to within 1 count of final reading on range.

DC AMPS RANGE	RESOLUTION	MAXIMUM BURDEN	ACCURACY [illegible]
200 μA	10 nA	0.3 V	0.15 + 2
2 mA	100 nA	0.3 V	0.15 + 2
20 mA	1 μA	0.3 V	0.15 + 2
200 mA	10 μA	0.3 V	0.2 + 2
2000 mA	100 μA	0.8 V	0.2 + 2
10 A	1 mA	0.3 V	0.5 + 2*

*Above 5A derate 0.15% rdg per amp for self-heating.

OVERLOAD PROTECTION: mA Input: 2A fuse (250V), externally accessible. **10A Input:** 20A for 15s, unfused.

SETTLING TIME: 1 second to within 1 count of final reading.

GENERAL

DISPLAY: Backlit 4½-digit LCD, 0.5 in. height; polarity, function, range, and status indication. Backlighting is switch-selectable.

RANGING: Auto or manual on DC volts, AC volts, ohms; manual on AC amps, DC amps.

AUTORANGING TIME: 300ms per range.

RELATIVE: Pushbutton allows zeroing of on range readings. Allows readings to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATA LOGGER and MIN/MAX: 100 reading storage capacity; records data at one of six selectable rates from 3 readings/second to 1 reading/hour. Also detects and stores maximum and minimum readings continuously in data logger mode.

CONVERSION RATE: 3 readings per second.

OVERRANGE INDICATION: "OL" displayed.

CREST FACTOR (ratio of peak value to rms value), AC FUNCTIONS: 3.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

COMMON MODE REJECTION RATIO (1kΩ unbalance): >120dB at DC, 50Hz, 60Hz ±0.15%. >60dB in AC volts.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C except ±(0.07%+2)/°C for 50Hz–10kHz in AC volts.

ENVIRONMENT: Operating: 0° to 50°C; <80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35° to 50°C. **Storage:** –40° to +70°C.

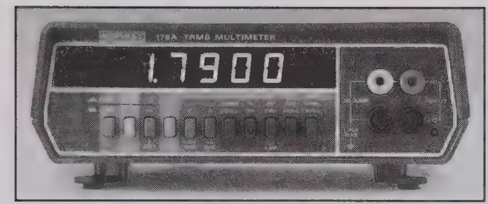
POWER: 105–125V or 210–250V (external switch selected), 90–110V available; 50–60Hz, 12VA. Removable power cord. Optional 6-8 hour battery pack, Model 1758.

DIMENSIONS, WEIGHT: 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (3 lbs., 14 oz.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, instruction manual.

4½-Digit DMMs

179A,177



177 MICROVOLT DMM
1.7700

- **179A: HI-LO ohms, 20A range**
- **177: 1μV/1mΩ/1nA**
- **4½-digit resoluton**
- **TRMS AC**
- **IEEE-488 output options**

IEEE-488

DC VOLTS

20 mV	1 μV	—	0.04 + 2
200 mV	10 μV	0.04 + 3	0.04 + 1
2 V	100 μV	0.04 + 1	0.03 + 1
20 V	1 mV	0.04 + 1	0.03 + 1
200 V	10 mV	0.04 + 1	0.03 + 1
1200 V	100 mV	0.04 + 1	0.035 + 1

[1] Accuracy is specified for 1 year, 18°–28°C, ±(%rdg + counts).

TEMPERATURE COEFFICIENT (0°–18°C & 28°–55°C), ±(%rdg +counts)/°C: 179A: ±(0.006% + 0.2)/°C except ±(0.006 + 0.4)/°C on 200mV range. **177:** ±(0.005% + 0.1)/°C except ±(0.005% + 0.6)/°C on 20mV range.

INPUT RESISTANCE: 10MΩ.

MAXIMUM ALLOWABLE INPUT: 1200V, limited to 10s below the 20V range.

NMRR: >60dB at 50Hz and 60Hz.

CMRR (1kΩ unbalance): >120dB at DC, 50Hz and 60Hz.

TRMS AC VOLTS

200 mV	10 μV	0.7 + 15	0.5 + 15
2 V	100 μV	0.6 + 15	0.5 + 15
20 V	1 mV	0.5 + 15	0.5 + 15
200 V	10 mV	0.5 + 15	0.5 + 15
1000 V	100 mV	0.5 + 15	0.5 + 15

[1] Accuracy is specified for 1 year (above 2000 counts), 18°–28°C, 100Hz–10kHz, ±(%rdg + counts).

EXTENDED FREQUENCY ACCURACY (179A): 45Hz–100Hz: ±(0.7% + 15). **10kHz–20kHz:** ±(0.8% + 15) on 20V and higher ranges; ±(1.5% + 15) on 2V range; ±(2% + 15) on 200mV range. **(177): 45Hz–20kHz:** ±(0.7% + 15).

CREST FACTOR (ratio of peak value to rms value): 3:1.

MAXIMUM ALLOWABLE INPUT VOLTAGE: 1000V rms, 1400V peak, 10^7V•Hz.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–55°C), ±(%rdg +counts)/°C: 179A (45Hz–10kHz): ±(0.07% + 2)/°C. **177 (45Hz–20kHz):** ±(0.05% + 2)/°C.

INPUT IMPEDANCE: 1MΩ shunted by <75pF.

CMRR (1kΩ unbalance): >60dB at DC, 50Hz and 60Hz.

DC & TRMS AC AMPS

20 μA	1 nA	—	—	0.2 + 2	—
200 μA	10 nA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
2 mA	100 nA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
20 mA	1 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
200 mA	10 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
2000 mA	100 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
20 A	1mA	0.5 + 2[4]	1 + 15[5]	—	—

[1] Accuracy specified for 1 year, 18°–28°C, ±(%rdg + counts).
[2] AC accuracy is specified at 45Hz–10kHz, above 2000 counts.
[3] Front panel zero. [4] Add 0.1% rdg above 15A for self-heating.
[5] ±1kHz max.

MAXIMUM INPUT: 2A, 250V DC or rms (fuse protected) except for 20A range on 179A: 15A continuous, 20A for 1 minute (unfused).

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C), ±(%rdg + counts)/°C:
179A: DC: ±(0.01% + 0.2). AC: ±(0.07% + 2).
177: DC: ±(0.01% + 0.2) except ±(0.01% + 0.6) on 20mA range. AC: ±(0.07 + 2).

MAXIMUM VOLTAGE BURDEN: 0.2V below 200mA range; 0.25V on 200mA range; 0.6V on 2000mA range; 0.5V on 20A range (179A).

GENERAL

DISPLAY: Five 0.5 in. LED digits w/decimal point and polarity indication.

CONVERSION PERIOD: 400ms.

OVERRANGE INDICATION: Display blinks all zeros above 19999 counts.

MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

ANALOG OUTPUT (177): Output Voltage: 1V = 10000 counts. **Output Resistance:** 5kΩ.

ENVIRONMENT: Operating: 0° to 55°C, 0 to 80% relative humidity up to 35°C. **Storage:** –25°C to +65°C.

POWER: 105–125V or 210–250V (switch selected), 90–110V available. 50–60Hz, 5.5W (179A) or 8W (177). Optional 6-hour battery pack.

ACCESSORIES SUPPLIED: Instruction manual. 179A supplied with Model 1691 Test Leads.

OHMS

20 Ω[3]	1mΩ	—	—	—	—	—	—	0.05 + 3	0.004 + 0.6	1mA
200 Ω[3]	10mΩ	—	—	—	—	—	—	0.05 + 2	0.004 + 0.2	1mA
2 kΩ	100mΩ	—	0.15+15	—	0.02+2	—	100 μA	0.04 + 1	0.004 + 0.2	1mA
20 kΩ	1 Ω	0.04+1	0.15+15	0.003+0.2	0.02+2	100 μA	10 μA	0.04 + 1	0.004 + 0.2	100 μA
200 kΩ	10 Ω	0.04+1	0.15+15	0.003+0.2	0.02+2	10 μA	1 μA	0.04 + 1	0.004 + 0.2	10 μA
2000 kΩ	100 Ω	0.04+1	0.15+15	0.003+0.2	0.03+2	1 μA	0.1 μA	0.04 + 1	0.005 + 0.2	1 μA
20MΩ	1 kΩ	0.10+1	—	0.02 +0.2	—	0.1 μA	—	0.10 + 1	0.02 + 0.2	0.1 μA

[1] Accuracy specified for 1 year, 18°–28°C, ±(%rdg + digits). [2] Temperature coefficient specified for 0°–18°C and 28°–50°C, ±(%rdg + counts)/°C. [3] 177 front panel zero.

MAX. INPUT: 179A: 1kV DC or peak AC for 10s, 450V rms continuous. **177:** 350V peak.

MAXIMUM OPEN CIRCUIT VOLTAGE: 5V.

MAXIMUM VOLTAGE ACROSS UNKNOWN ON RANGE (179A): 2V on HI Ω, 0.2V on LO Ω.

ORDERING INFORMATION

179A configurations include Instruction Manual and Model 1691 General Purpose Test Leads.

179A TRMS DMM

179A/1788 TRMS DMM with Rechargeable Battery Pack

179A/1792 TRMS DMM with BCD Output

179A/1793 TRMS DMM with IEEE-488 Output

177 configurations include Instruction Manual .

177 Microvolt DMM

177/1788 Microvolt DMM with Rechargeable Battery Pack

177/1792 Microvolt DMM with BCD Output

177/1793 Microvolt DMM with IEEE-488 Output

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS

1681	Clip-On Test Lead Set
1683	Universal Test Lead Kit
1691	General Purpose Test Leads

CABLES, ADAPTERS

7007-1, -2	Shielded IEEE-488 Cables, 1m (3.2 ft.) & 2m (6.5 ft.)
7008-3, -6	IEEE-488 Digital Cables, 0.9m (3 ft.) and 1.8m (6 ft.)

PROBES/SHUNT

1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe

OUTPUTS

1792	Isolated BCD Output
1793	Isolated IEEE-488 Output

POWER

1788	Rechargeable Battery Pack

RACK MOUNT KITS

1010	Single Rack Mount Kit
1017	Dual Rack Mount Kit

CARRYING CASES

1684	Hard Shell Carrying Case
1686	Vinyl Carrying Case

OTHER

1779	Spare Parts Kit (177)

See page 163 for descriptions of all accessories.

3½-Digit DMM

- **Display annunciators indicate range and function**
- **2000 hour battery life**
- **Line power option**
- **Extensive input protection**

ORDERING INFORMATION

169
Portable/Bench DMM with Operator's Manual, Model 1691 General Purpose Test Lead Set and C-Zn Batteries

169/1766
Portable/Bench DMM with Operator's Manual, Model 1691 General Purpose Test Lead Set and Battery Eliminator installed

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS

1681	Clip-On Test Lead Set
1683	Universal Test Lead Kit
1691	General Purpose Test Leads

PROBES/SHUNT

1301	Temperature Probe
1600A	High Voltage Probe
1651	50A Current Shunt
1682A	RF Probe
1685	Clamp-On Current Probe

POWER

1766	Battery Eliminator

RACK MOUNT KITS

1010	Single Fixed Rack Mount Kit
1017	Dual Fixed Rack Mount Kit

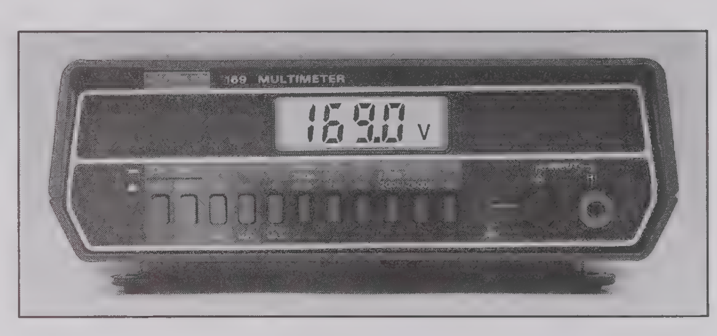
CARRYING CASES

1684	Hard Shell Carrying Case
1686	Vinyl Carrying Case

OTHER

1699	Spare Parts Kit

See page 163 for descriptions of all accessories.



The Keithley 169 provides full capability for many general purpose applications. It has five functions; DC volts, DC amps, AC volts, AC amps, and ohms. Sensitive down to 100μV, 100nA, and 100mΩ, the 169 spans the most used ranges up to 1000V, 2A, and 20MΩ. The full bench-sized case, molded from impact-resistant flame-retardant plastic, is the same case used on more sophisticated Keithley DMMs. Full input protection prevents damage; voltage ranges are protected to 1400V peak, ohms is protected to 300V rms, and current ranges are protected by an externally accessible 2A (250V) fuse.

The 169 has both range and function annunciators. Pushbutton switches are color-coded to the front panel. Two input jacks and auto polarity mean no lead changing.

By using alkaline batteries, 2000 hours (1 year) of operation can be expected. Thus, battery life can be the same as the calibration cycle. Only one calibration adjustment is required. MTBF is 20,000 hours, so most units will never need repair. If they do, all components are on one easily accessible PC board.

A line power option, Model 1766, can be installed in place of the batteries. This option, which includes a fully isolated power supply and 3-wire grounded line cord, operates over the entire voltage range of 105–250V AC, 50–60Hz, without switching.

DC VOLTS		ACCURACY (1 Year)
		±(%rdg + counts)
RANGE	RESOLUTION	18°–28°C
200 mV	100 μV	0.25 + 1
2 V	1 mV	0.25 + 1
20 V	10 mV	0.25 + 1
200 V	100 mV	0.25 + 1
1000 V	1 V	0.25 + 1

MAXIMUM ALLOWABLE INPUT: 1000V DC, 1400V peak AC.

INPUT RESISTANCE: 10MΩ.

NORMAL MODE REJECTION RATIO: >50dB at 50Hz, 60Hz.

COMMON MODE REJECTION RATIO: >100dB at DC, 50Hz and 60Hz (1kΩ unbalance, 500V).

AC VOLTS		ACCURACY (1 Year)	
		±(%rdg + counts)	
		18°–28°C	
RANGE	RESOLUTION	45Hz–1kHz	1kHz–10kHz
200 mV	100 μV	1 + 5	6 + 7
2 V	1 mV	1 + 5	6 + 7
20 V	10 mV	1 + 5	6 + 7
200 V	100 mV	1 + 5	6 + 7
1000 V	1 V	1 + 5	6 + 7

MAXIMUM ALLOWABLE INPUT: 1000V rms, 1400V peak, 10^6 V•Hz, continuous except 200mV range: 350V continuous, 15s maximum above 350V.

RESPONSE: Average responding, calibrated in rms of a sine wave.

INPUT IMPEDANCE: 10MΩ shunted by <100pF.

OHMS		ACCURACY (1 Year) ±(%rdg + counts)	FULL-SCALE
RANGE	RESOLUTION	18°–28°C	VOLTAGE
200 Ω	100 mΩ	0.3 + 3	<0.5V
2 kΩ	1 Ω	0.2 + 1	>0.5V
20 kΩ	10 Ω	0.2 + 1	>0.7V
200 kΩ	100 Ω	0.2 + 1	>0.7V
2000 kΩ	1 kΩ	0.2 + 1	>0.7V
20 MΩ	10 kΩ	2.0 + 1	>0.7V

MAXIMUM OPEN CIRCUIT VOLTAGE: 1.5V except 200Ω range: 3.5V.

MAXIMUM ALLOWABLE INPUT: 315V DC or rms.

DC AMPS		ACCURACY (1 Year)	MAXIMUM
	RESO-	±(%rdg + counts)	VOLTAGE
RANGE	LUTION	18°–28°C	BURDEN
200 μA	100 nA	0.75 + 1	0.25V
2 mA	1 μA	0.75 + 1	0.25V
20 mA	10 μA	0.75 + 1	0.25V
200 mA	100 μA	0.75 + 1	0.3 V
2000 mA	1 mA	0.75 + 1	0.7 V

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

AC AMPS		ACCURACY (1 Year)	MAXIMUM
	RESO-	±(%rdg + counts)	VOLTAGE
RANGE	LUTION	18°–28°C	BURDEN
200 μA	100 nA	1.5 + 1	0.25V
2 mA	1 μA	1.5 + 1	0.25V
20 mA	10 μA	1.5 + 1	0.25V
200 mA	100 μA	1.5 + 1	0.3 V
2000 mA	1 mA	1.5 + 1	0.7 V

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

GENERAL

DISPLAY: 3½-digit LCD, 0.6 in. numeral height with polarity, range, and function annunciators.

OVERRANGE INDICATION: 3 least significant digits blanked.

MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

OPERATING ENVIRONMENT: 0° to 50°C, <80% RH up to 35°C, <70% RH from 35° to 60°C.

STORAGE ENVIRONMENT: –35° to 60°C.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <±(0.1 × applicable accuracy specification)/°C.

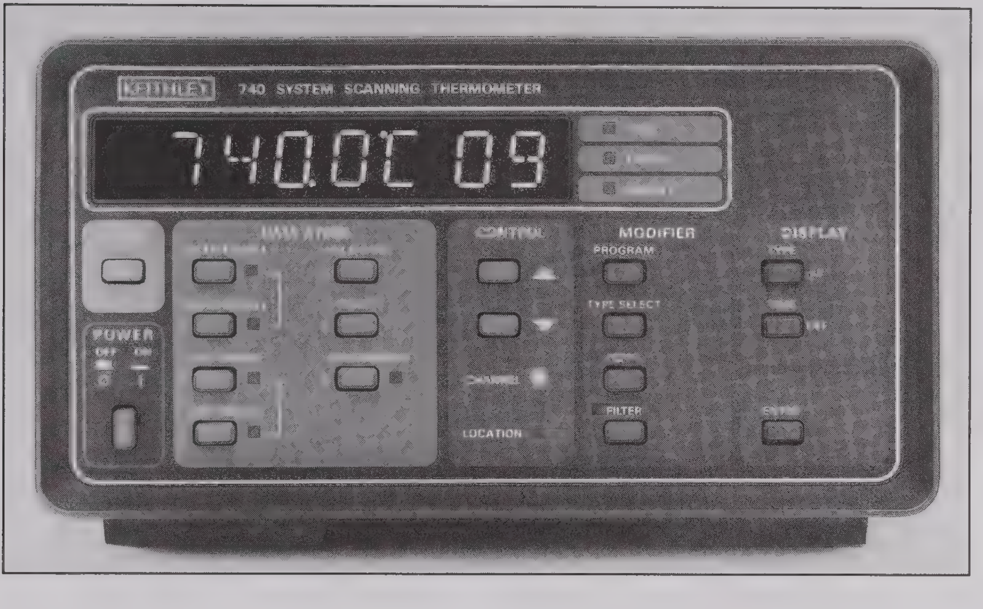
POWER: Six 1.5V C cells. Battery life 1000 hours typical with C-Zn cells, 2000 hours with alkaline cells.

BATTERY INDICATOR: Display indicates "BAT" when less than 5% of battery life remains.

DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.4kg (3 lbs.).

ACCESSORIES SUPPLIED: Model 1691 Test Lead Set, operator's manual.

Scanning Thermometer



The Model 740 Programmable Thermometer has a built-in reference junction and will linearize any of 7 different thermocouple types. The Model 740/7402 combination includes nine channels of thermocouple input. An IEEE-488 interface port is included for easy system integration or connection to an IEEE-488 printer for data logging.

Input Expansion

The Model 740/7402 can be expanded up to 81 inputs by selecting a Model 705 or 706 Scanner and configuring these with additional 7402 or 7057A thermocouple scanner cards, each with 9 inputs. The control for these expansion units is through a serial loop connected by standard coaxial cable, thereby allowing expansion without using additional IEEE-488 addresses.

Input Programming

Each input can be selected for any of J, K, T, E, R, S, or B type thermocouples, or for voltage readback up to 100mV with 1μV sensitivity. Any input can also be turned off, allowing the instrument to skip that channel in the scan sequences. Open thermocouple conditions are detected and displayed.

Monitor Temperature Trends

A single input can be read at programmable intervals to monitor temperature trends. Rates up to 20 readings/second are available for determining rapid temperature variations, and the data can be stored in the internal memory. Data can also be transferred to a computer file over the built-in IEEE-488 bus.

Locate hot spots and examine time-dependent thermal characteristics. Scan intervals are programmable, and the maximum rate of 20 readings/second assures a minimum of time skew between input samples for monitoring temperature changes.

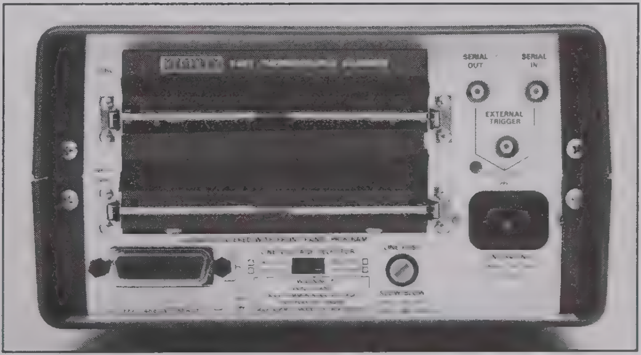
A SMART PRINT feature can locate the address and send data to any IEEE-488 printer for data logging of results in a bench configuration.

Non-Volatile Memory

An internal memory stores up to 100 readings. Data can be recalled from the front panel or transferred in a block transfer to a controller. The Model 740 will also give HI, LO, and AVERAGE of the data memory.

Simple, Reliable Calibration

Calibration of the Model 740 is easy—there are no mechanical adjustments. Simply present the calibration voltages to the input and tell the instrument to calibrate. Constants are stored in non-volatile memory to maintain the instrument's accuracy.



- Scan 9 thermocouple inputs
- Expand to 81 inputs
- Thermocouple types J, K, T, E, R, S, or B
- °C, °F, or mV readings
- Store temperature profiles
- Record temperature trends

IEEE-488

[illegible]

740
System Scanning Thermometer with Instruction Manual

740/7402
Scanning Thermometer with 9 Input Channels and Instruction Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5:	BNC Interconnect Cable, 1.5m (5 ft.)

RACK MOUNT KITS

1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

OTHER

7057A	Thermocouple Scanner Card
7401	Thermocouple Wire Kit, 30m (100 ft.), Type K
7402	Thermocouple Scanner Card

See page 163 for descriptions of all accessories.

740 Scanning Thermometer

ACCURACY*

TYPE	RANGE	[illegible]
mV	–99.999 to 100.000 mV	±(0.02% + 3 µV)
J	–100.0 °C to +760.0°C –148.0 °F to +1000.0°F	±0.4°C ±0.8°F
K	–100.0 °C to +1372.0°C –148.0 °F to +2501.0°F	±0.5°C ±0.9°F
T	–100.0 °C to +400.0°C –148.0 °F to +752.0°F	±0.5°C ±0.8°F
E	–100.0 °C to +1000.0°C –148.0 °F to +1832.0°F	±0.5°C ±0.9°F
R	0 °C to +1780 °C +32 °F to +3236 °F	±1 °C ±2 °F
S	0 °C to +1780 °C +32 °F to +3236 °F	±1 °C ±2 °F
B	+350 °C to +1820 °C +602 °F to +3368 °F	±1 °C ±2 °F
EXTENDED RANGE (Types J, K, T, E)		
	–200.0 °C to – 100.1 °C –328.0 °F to – 148.0°F	±0.6°C ±1.0°F

mV INPUT RESISTANCE: >1GΩ.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): <(0.1 × rated accuracy)/°C.

INPUT CURRENT: 800pA maximum during measurement; 60µA maximum during open thermocouple check.

COMMON MODE REJECTION RATIO (at DC, 50 and 60Hz, 100Ω unbalance):** <0.0003°C/V with filter enabled (160dB); <0.003°C/V with filter disabled (140dB).

NORMAL MODE REJECTION RATIO (at 50 and 60Hz):** <0.003°C/mV with filter enabled (80dB); <0.03°C/mV with filter disabled (60dB).

*Excludes thermocouple errors (specifications include Model 7057A errors).

**Based on >36µV/°C slope.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD, MLA, MTA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, E1, C28.

PROGRAMMABLE PARAMETERS: EOI, Terminator, SRQ, Status, Trigger, Self Test, Calibration, Filter, Function, Scan Interval, Log Interval, Time & Date, Time of Day Trigger, Date Format, Alarm Limits, Output Format, Channel Number, Data Buffer, Scale, Display, Channel Type.

GENERAL

MAXIMUM ALLOWABLE INPUT: 250V rms, 350V peak (for one minute).

MAXIMUM COMMON MODE VOLTAGE: 200V peak to earth.

MAXIMUM THERMOCOUPLE LOOP RESISTANCE: 1kΩ.

FILTER SETTLING TIME: 100ms (typical).

SCANNING RATE: >20 channels/second, filter disabled; >5 channels/second, filter enabled.

BENCH READING RATE: 8 readings/second, filter disabled; 4 readings/second, filter enabled.

LOGGING INTERVAL: One of 12 selectable rates from 50ms to 1 hour, or triggered.

SCANNING INTERVAL: One of 10 selectable rates from 500ms to 1 hour, or triggered.

DISPLAY: Eight 0.5-inch alphanumeric LED digits with decimal point and polarity. Function, Filter, Channel, Location, Overflow, Open Thermocouple, and IEEE bus status also displayed.

INTERNAL CLOCK: Displays hour/minute/second; <1 minute/month error (typical).

WARM-UP: 1 hour to rated accuracy.

CONNECTORS: 3 BNC: External Trigger, Serial-In, Serial-Out (TTL compatible). Quick disconnect connectors on input card.

CHANNEL CONFIGURATION: Types J, K, T, E, R, S, B, mV, or Off for each channel.

DATA MEMORY: Battery backed up one week minimum.

- **Single Channel Log:** 100 locations (reading, location, time taken).
- **Multi-Channel Scan:** 90 locations (reading, channel number, time taken)
- **Configuration:** 81 locations (channel type selected).

CAPACITY: Single channel or 10 channels (including reference junction) using one 7402 or 7057A thermocouple scanner card. Up to 90 channels (including reference junctions) using 8 additional thermocouple scanner cards and one Model 706 or four Model 705 scanners.

OPERATING ENVIRONMENT: 0°–50°C; <80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°–50°C.

STORAGE ENVIRONMENT: –25° to +60°C.

POWER: 105–125V or 210–250V (external switch selected), 20VA, 90–110V available; 50–60Hz.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.0kg (9 lbs.).

ACCESSORY SUPPLIED: Instruction manual.

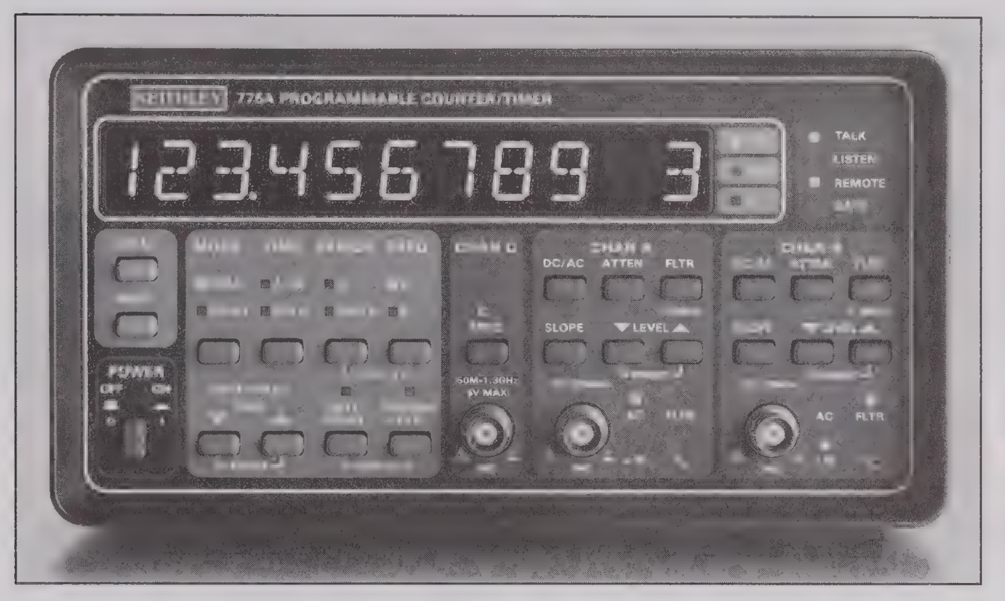
Temperature Measurements

Keithley provides instruments that allow temperature measurements to be made using RTDs or thermocouples. RTDs are generally more accurate, while thermocouples are often less expensive. In two instruments, the 195A and 193A, temperature capability is built into high performance DMMs. In the 740 Scanning Thermometer, multiple inputs for high quality data acquisition are provided.

TEMPERATURE MEASUREMENTS SELECTOR GUIDE

MODEL	740	195A	193A
Number of Inputs	1 to 9 standard Up to 81 using scanner	1	1
RTD TEMPERATURE MEASUREMENT			
Temperature Span		–328° to +630°C	–100° to +630°C
Basic Resolution		0.01°C	0.01°C
Basic Accuracy		1°C	0.18°C
RTD Type		100Ω platinum, DIN 43760 or IPTS-68, programmable alpha & delta	100Ω platinum, DIN 43760 or IPTS-68
THERMOCOUPLE TEMPERATURE MEASUREMENT			
Temp. Span	–148° to +1820°C		–100° to +1372°C
Basic Resolution	0.1°C		0.1°C
Basic Accuracy	0.4°C		0.5°C
Ref. Junction	Internal		External
TC Types	J K T E R S B		J K T E
Display Units	°F, °C, mV	°F, °C	°F, °C
Reading Rate	8/second	1.2/second	5/second
Overload Protection	250V peak	360V peak	350V peak
Max. Common Mode Voltage	200V peak	500V peak	500V peak
Special Features	Scanning interval real-time clock		
Data Memory	100 points (incl. channel no. and time)	100 points	500 points

Programmable Counter/Timer 775A



Keithley's Model 775A Programmable Counter/Timer brings you nine digits of resolution per second and six functions. The 775A uses two identical channels (A and B), each measuring frequency from DC to 120MHz. In addition, you can measure period, period average, time interval A to B, totalize, and pulse width using Channel A. For low frequency and slow transition events, a selectable 100kHz low pass filter prevents the instrument from triggering on noise.

Reciprocal Counting

The 775A uses a reciprocal counting technique to yield 9 digits of resolution, even when measuring low frequency signals. Nine digit per second resolution is achieved by multiplying the 10MHz clock frequency to an effective frequency of 100MHz. This microprocessor-based technique is usually found only in more expensive instruments.

Choice of Time Bases

Keithley offers a standard 10MHz time base with better than 0.5ppm/month stability. A TCXO (temperature compensated crystal oscillator) is included with the Channel C option; or, an external reference can be input.

Triggers

Flexible triggering with programmable control over levels, slope, coupling, and delay assure repeatable measurements on difficult waveforms. Trigger levels are variable in 10mV steps from –2.50 to +2.50 volts. A fast search mode rapidly sequences through the range of trigger levels until a valid trigger is detected; this can also be used to determine positive and negative waveform peaks. Programmable trigger delay can hold off the measurement for circuit settling.

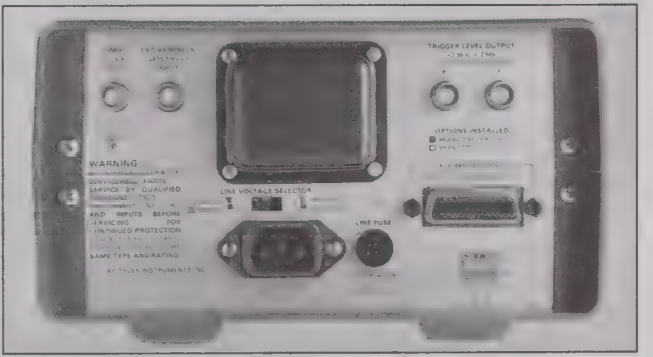
Options

The 775A is available with a Channel C input for frequency measurements from 50MHz to 1.3GHz. This option also includes a TCXO with 0.1ppm/month stability.

System Compatibility

IEEE-488 interface is included in the base price. System features such as external arming and gate/delay input assure flexibility. And all bench controls are programmable.

The 775A is both easy to use and easy to integrate into your system. Simple mnemonic commands simplify programming, and consistent bus implementation with other Keithley instruments assures predictable bus operation.



- 9 digits/second resolution
- Dual input
- Optional Channel C and TCXO
- IEEE-488 programmable

IEEE-488

[illegible]

775A
Programmable Counter/Timer

775A/51/52
Programmable Counter/Timer with Channel C and TCXO

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5:	BNC Interconnect Cable, 1.5m (5 ft.)
7754-3	BNC to Alligator Cable, 0.9m (3 ft.)

RACK MOUNT KITS

1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

OTHER

7755	50Ω Feed-Through Terminator

See page 163 for descriptions of all accessories.

775A Programmable Counter/Timer

INPUT CHARACTERISTICS (Ch. A & B, [illegible])

RANGE: 0 to 120MHz, DC coupled; 30Hz to 120MHz, AC coupled.

SENSITIVITY (×1): 25mV rms, <10MHz; 50mV rms,)10MHz.

DYNAMIC RANGE (×1): 50mV to 5V p-p, <20MHz; 140mV to 2.5V p-p, >20MHz.

COUPLING: AC or DC, switchable.

IMPEDANCE: 1MΩ nominal, shunted by <60pF.

ATTENUATOR: ×1 or ×10 nominal, switchable.

LOW PASS FILTER: –10dB at 160kHz nominal, switchable.

SIGNAL OPERATING RANGE (×1): –2.55V DC to +2.55V DC.

TRIGGER LEVEL: –2.55 to +2.55V DC, ×1; –25.5 to +25.5V DC, ×10.

TRIGGER LEVEL RESOLUTION: 10mV, ×1; 100mV, ×10.

TRIGGER LEVEL SETTLING ACCURACY: ±(35mV + 2% setting), ×1; ±(350mV + 2% setting), ×10.

TRIGGER LEVEL SETTLING OUTPUT: Via rear panel BNC, not adjusted for attenuators.

SLOPE: + or – slope, switchable.

DAMAGE LEVEL:	×1:	DC– 2 kHz	250V DC + peak AC
		2 kHz– 100 kHz	5 × 10^{5}V rms • Hz/frequency
		>100 kHz	5V rms
	×10:	DC– 20 kHz	250V DC + peak AC
		20 kHz– 100 kHz	5 × 10^{5}V rms • Hz/frequency
		>100 kHz	50V rms

OPTION CONFIGURATION (Model 775A/51/52 only)

Channel C: Frequency

RANGE: 50MHz to 1.3GHz.

COUPLING: AC.

IMPEDANCE: 50Ω.

SENSITIVITY: 15mV, 50MHz to 1.0GHz; 25mV, 1.0GHz to 1.2GHz; 75mV, 1.2GHz to 1.3GHz.

DYNAMIC RANGE: 25mV rms to 1V rms.

DAMAGE LEVEL: DC–100kHz: 15V DC + peak AC; >100kHz: 5V rms.

TCXO

FREQUENCY: 10MHz.

AGING RATE: <1 × 10^{-7}/month.

TEMPERATURE: ±1 × 10^{-6}, 0° to 40°C, ref. 25°C.

LINE VOLTAGE: <1 × 10^{-7} for 10% change.

TIME BASE OUT: 2V min. @ 10MHz, 100 output resistance, via rear panel BNC.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All front panel controls (except Power) plus Reading Rate, Data Format, Trigger, EOI, Terminator, Service Request, Self Test, Display, Status.

READING RATES: One shot, normal (3/s), fast (25/s), or dump (140/s).

GENERAL

DISPLAY: Nine LED digits with decimal point and exponent.

BENCH READING RATES: One shot or normal (3/second).

ARMING (TRIGGER): Each channel is armed by its own signal; or RESET button or EXT ARMING input when in one shot (HOLD) mode.

ARMING DELAY: 30µs in Frequency and Period Average; 10µs in Period, Time Interval, and Pulse Width.

EXTERNAL ARMING INPUT: Positive edge TTL signal via rear panel BNC.

EXTERNAL TIME BASE INPUT: 10MHz TTL signal via rear panel BNC.

GATE: LED indicator lights when gate is open.

WARM-UP: 2 hours to rated accuracy.

OPERATING TEMPERATURE: 0° to 40°C, 0% to 80% relative humidity.

STORAGE TEMPERATURE: –25° to 65°C.

POWER: 105–125V or 210–250V (rear panel switch selected), 50–60Hz, 35VA max. 90–110V available.

DIMENSIONS, WEIGHT: 127mm high × 215mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.5kg (8 lbs.).

ACCESSORY SUPPLIED: Instruction manual.

FREQUENCY A, B

RANGE: 0.1Hz to 120MHz.

LSD DISPLAYED: (10ns × frequency)/gate time.

RESOLUTION: ±1 LSD ± [(1.4 × trigger error + 2ns) × frequency]/gate time.

ACCURACY: ±Resolution ± (time base error × frequency).

DIGITS DISPLAYED: 8 per second of gate time, minimum.

PERIOD A

RANGE: 10ns to 10^4 seconds.

LSD DISPLAYED: 10ns to 0.1ms

ACCURACY: ±1 LSD ± (time base error × period) ± trigger error.

PERIOD AVERAGE A

RANGE: 10ns to 10 seconds.

LSD DISPLAYED: (10ns × period)/gate time.

RESOLUTION: ±1 LSD ± [(1.4 × trigger error + 2ns) × frequency]/gate time.

ACCURACY: ±Resolution ± (time base error × period).

NUMBER OF PERIODS AVERAGED: Gate time/period.

GATE/DELAY

INTERNAL GATE TIME: Variable from 100µs to 10 seconds in 45 increments, or one period of the input, whichever is longer. May be used in frequency and period average measurements.

EXTERNAL GATE TIME: Continuously variable from 100µs to 10 seconds, or one period of the input, whichever is longer.

EXTERNAL GATE DELAY: 10µs + one period of the input signal, maximum.

INTERNAL DELAY TIME: Variable from 100µs to 10s in 45 increments. May be used in period, time interval, and pulse width measurements.

EXTERNAL DELAY TIME: Continuously variable from 100µs to >1 hour.

EXTERNAL GATE/DELAY INPUT: Positive TTL signal via rear panel BNC.

TIME INTERVAL A→B

RANGE: 10ns to 10^4 seconds.

LSD DISPLAYED: 10ns to 0.1ms.

ACCURACY: ± 1 LSD ± (time base error × time interval) ± trigger error ± trigger timing error ± 2ns.

PULSE WIDTH A (Positive or Negative)

RANGE: 10ns to 10^4 seconds.

LSD DISPLAYED: 10ns to 0.1ms.

ACCURACY: ± 1 LSD ± (time base error × pulse width) ± trigger error ± trigger timing error ± 2ns.

TOTALIZE

MODES: A gated by B; cumulative.

RANGE: 0 to 10^{16} – 1.

REPETITION RATE: 120MHz maximum.

ACCURACY: ±LSD.

LSD DISPLAYED: 1 count up to 10^{10} – 1; beyond 10^{10} – 1 use (1 part in 10^9 × displayed exponent).

TIME BASE

FREQUENCY: 10MHz.

AGING RATE: ≤5 × 10^{-7}/month.

TEMPERATURE: ±5 × 10^{-6}, 0° to 40°C, ref. 25°C.

TIME BASE OUT: 2V minimum @ 10MHz, 100Ω output resistance.

Sensitive Measurements

ELECTROMETERS AND PICOAMMETERS

Selector Guide 48

Technical Data 49

617 Electrometer/Source 53

617-HIQ Electrometer/Source 53

614 Digital Electrometer 55

642 Digital Electrometer 57

642 LNFPA Digital Electrometer 57

602 Electrometer 59

610C Electrometer 59

CURRENT MEASUREMENTS

486 Picoammeter 60

487 Picoammeter/Source 60

485 Autoranging Digital Picoammeter 62

480 Digital Picoammeter 62

428 Current Amplifier 64

VOLTAGE MEASUREMENTS

Technical Data 66

182 Sensitive Digital Voltmeter 68

181 Nanovoltmeter 70

155 Null Detector/Microvoltmeter 71

Model 78 Nanovolt Scanner System 72

262 Low Thermal Voltage Divider 72

RESISTANCE MEASUREMENTS

580 Micro-Ohmmeter 73

Selector Guides

	ELECTROMETERS					SOURCE-MEASURE UNITS			CALIBRATOR/ SOURCE
MODEL	602	610C	614	617	642	236	237	238	263
Page	59	59	55	53	57	84	84	84	153
CURRENT									
From	1 fA	1 fA	10 fA	100 aA	10 aA	10 fA	10 fA	10 fA	50 aA
To	300 mA	300 mA	2 mA	20 mA	100 nA	100 mA	100 mA	1 A	20 mA
VOLTAGE									
From	10 µV	10 µV	10 µV	10 µV	20 µV	10 µV	10 µV	10 µV	5 µV
To	10 V	100 V	20 V	200 V	11 V	110 V	1100 V	110 V	20 V
RESISTANCE[1]									
From	10 Ω	1 Ω	1 Ω	100 mΩ	N/A	100 µΩ	100 µΩ	10 µΩ	1 kΩ
To	10 TΩ	100 TΩ	200 GΩ	10 PΩ		1 PΩ	10 PΩ	1 PΩ	100 GΩ
CHARGE[2]									
From	1 fC	1 fC	10 fC	10 fC	800 aC	N/A	N/A	N/A	0.5 fC
To	1 µC	10 µC	20 nC	20 nC	100 pC				20 µC
Input Connection	Triax	UHF	Triax	Triax	BNC, special sapphire adapter	Triax	Triax	Triax	Triax
Special Features	Battery power. Analog. Floating input.	Low cost. Analog.	4½ digits. Low cost. Current suppression. Battery power.	4½ digits. Autoranging. IEEE-488 programmable. Built-in 100V source.	4½ digits. High sensitivity. BCD, IEEE-488 output options.	Source/measure capability. High speed. 5 digits. Autoranging. IEEE-488.			5½ digits. Calibrator source. Secondary standard. IEEE-488.

[1] Resistance is measured with the 236, 237 and 238 using Source V/Measure I or Source I/Measure V.

[2] Model 617-HIQ measures from 10pC to 20µC.

	CURRENT AMPLIFIER	PICOAMMETERS			
MODEL	428	480	485	486	487
Page	64	62	62	60	60
CURRENT					
From	1.2 fA	1 pA	100 fA	10 fA	10 fA
To	10 mA	2 mA	2 mA	2 nA	2 nA
Input Connection	BNC	BNC	BNC	Triax	Triax
Special Features	2 µs rise time. 10^{11}V/A gain.	4½ digits. LED display.	4½ digits. Autoranging.	180 rdg/s. IEEE-488.	±500V source. IEEE-488.

The goal of any electrical current measurement is to insert an ammeter in the circuit in a way that allows the current indicated on the ammeter to be equal to the current originally flowing through the circuit under test (see **Figure 1a**). This measurement is to be carried out to within some acceptable uncertainty. Any ammeter can be modeled to consist of three separate circuit elements shown in **Figure 1b**: a shunt resistance R_{SH} that arises from the cable connected to the meter; a generator of unwanted electrical current I_E, which represents mainly currents generated by the cabling and connectors; and an internal meter resistance R_M, which includes series cable resistance. The internal resistance is in series with an ideal ammeter M_I having no resistance or current source of its own.

When the ammeter is connected in the circuit, the current indicated on the meter is equal to the current that would flow through the circuit if the ammeter were not inserted, plus or minus errors due to elements in the circuit model. These errors consist of current I_{SH} flowing through shunt resistance R_{SH}, currents generated in the interconnection I_E, inherent meter uncertainty U_M, and errors induced by voltage burden (or drop) V_M across the ammeter.

FIGURE 1a

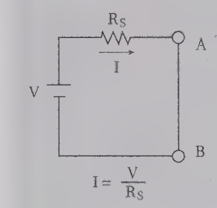
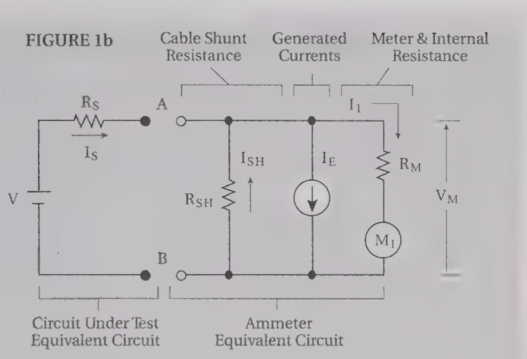


FIGURE 1a: A source causes a current (I) to flow through a wire between A and B.

FIGURE 1b



$$\underbrace{I_M}_{\text{Indicated Current}} = \underbrace{\frac{V}{R_S}}_{\text{Current to be Measured}} - \underbrace{\frac{V_M}{R_S}}_{\text{Voltage Burden Error}} - \underbrace{I_{SH}}_{\text{Shunt Current Error}} - \underbrace{I_E}_{\text{Generated Current Error}} \pm \underbrace{U_M}_{\text{Meter Uncertainty}}$$

When an ammeter and connecting cable are used in place of a wire between A and B, a voltage burden V_M is developed which forces a shunt current I_{SH} through the shunt resistance R_{SH} of the cable. Unwanted error currents I_E are also generated due to various phenomena discussed in the text.

SHUNT vs. FEEDBACK AMMETERS

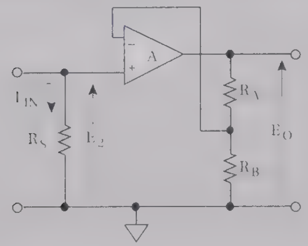
There are two techniques for making low-current measurements: the shunt ammeter and the feedback ammeter technique. Picoammeters and the AMPS function of newer electrometers use the feedback ammeter configuration only. The major difference between picoammeters and electrometers is that electrometers are multifunction instruments while picoammeters measure only current.

Shunt Ammeter

Shunting the input of a voltmeter with a resistor forms a shunt ammeter (**Figure 2**). For any given I_{IN}, several combinations of R_S and voltage sensitivity are possible.

This circuit is typically used in sensitive DMMs, which have a voltage burden of 200mV or more.

FIGURE 2: Shunt Ammeter



$$E_2 = I_{IN} R_S$$

$$E_O = E_2 \left[\frac{R_A + R_B}{R_B} \right] = I_{IN} R_S \left[\frac{R_A + R_B}{R_B} \right]$$

Feedback Ammeter

In this configuration, shown in **Figure 3**, the input current (I) flows through the feedback resistor R_F. The low offset current of amplifier A changes the current I by a negligible amount. Circuit analysis shows:

$$E_O + IR_F = E_1$$

$$E_O = -AE_1 \text{, and } E_1 = -\frac{E_O}{A}$$

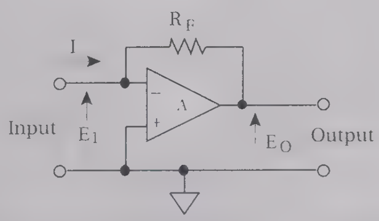
$$\text{Thus, } E_O + IR_F = -\frac{E_O}{A}$$

$$\text{and } E_O \left[1 + \frac{1}{A} \right] = -IR_F .$$

$$\text{Since } A \gg 1,\ E_O = -IR_F$$

$$\text{and } |E_1| = \frac{E_O}{A} \ll E_O$$

FIGURE 3: Feedback Ammeter



Thus the output voltage is a measure of input current. Sensitivity is determined by the feedback resistor R_F. The low voltage burden E_1 and corresponding fast rise time are achieved by the high gain op amp which forces E_1 to be nearly zero.

Typical voltage burdens of picoammeters and electrometers using this circuit are 200µV to 1mV.

SOURCES OF GENERATED CURRENT ERROR

Errors in current-measuring instruments arise from currents generated in various circuit elements. The current I_M indicated on a current meter is actually equal to the current I_1 through the meter, plus or minus some meter uncertainty U_M (**see Figure 1b**). I_1 is the sum of the signal current I_S less shunt current I_{SH} and the sum of all generated currents I_E.

Noise Currents

Current generators at various points in the circuit are summed to form a total error current I_E in **Figure 1b.** These currents may arise from triboelectric, piezoelectric, and electrochemical effects, or resistive leakage. The sum of error currents in the measurement instrument is included in the specifications of the instrument.

Triboelectric currents (**Figure 4**) are generated by charges created at the interface between a conductor and an insulator due to friction. Here, free electrons rub off the insulator and create a charge imbalance that causes the current flow. A typical example would be currents generated by insulators and conductors rubbing together in a coaxial cable.

FIGURE 4: Triboelectric Effect

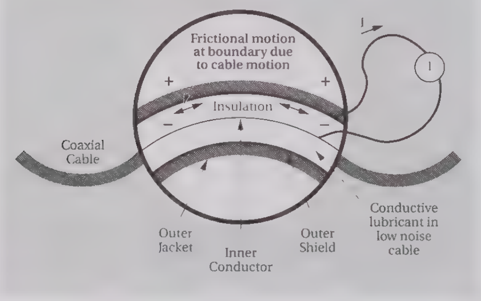
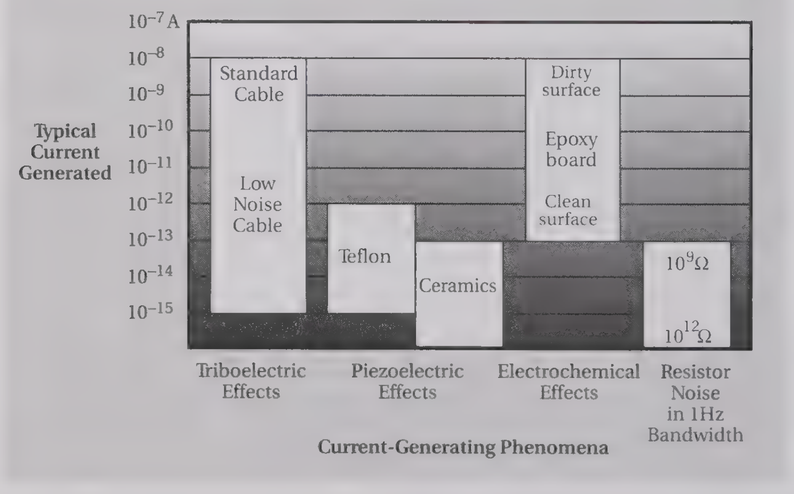
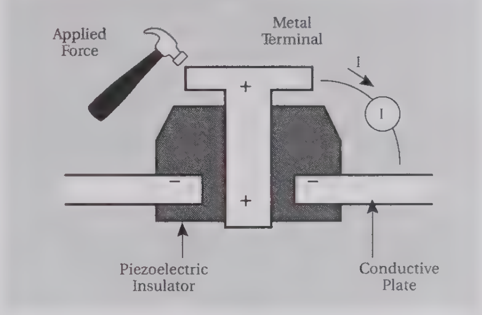

Frictional motion at boundary due to cable motion
I
I
+
+
Insulation
–
–
Coaxial Cable
Outer Jacket
Inner Conductor
Outer Shield
Conductive lubricant in low noise cable

FIGURE 7: Typical Magnitudes of Current Generated Due to Low Current Phenomena



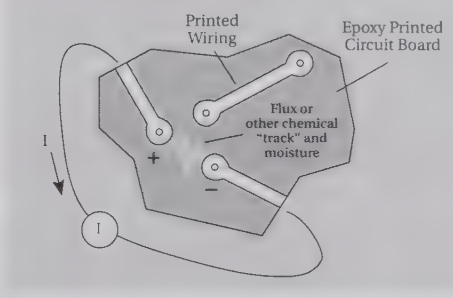
Piezoelectric currents (**Figure 5**) are generated when mechanical stress is applied to certain insulating materials which generate a charge when stressed. The effect occurs in some ceramics and other crystalline materials, as well as some plastics used for insulated terminals and interconnecting hardware.

FIGURE 5: Piezoelectric Effect


Applied Force
Metal Terminal
I
I
+
+
–
–
Piezoelectric Insulator
Conductive Plate

Noise currents also arise form electrochemical effects (**Figure 6**) when ionic chemicals create weak currents between conductors on a substrate. For example, commonly used epoxy printed circuit boards, when not thoroughly cleaned of etching solution, flux, or other material, can generate currents of a few nanoamps between board conductors. To prevent these currents, Freon or methanol should be used to remove any contaminants from the assembled printed circuit board.

FIGURE 6: Electrochemical Effect


Printed Wiring
Epoxy Printed Circuit Board
Flux or other chemical "track" and moisture
I
+
–
I

Current is also generated by thermal activity in the shunt resistance. This current (i.e. Johnson noise) is given by:

$I = \sqrt{4kTF/R}$

where K is Boltzmann's constant, T is temperature in °K, F is noise bandwidth, and R is the resistance value. Generally, this current can be ignored when measuring above 10^{-14}A.

Figure 7 summarizes approximate magnitudes of the various current generating effects.

HIGH RESISTANCE MEASUREMENTS

Low current measurement techniques must often be used to determine the value of high resistances. In some cases a constant voltage technique is used. Here, a constant voltage source is impressed across the resistance to be measured, and the resulting current is read from a series ammeter to indicate resistance. This measurement technique provides the advantage of rigidly defining the voltage used in the test. Test voltage is an important parameter for many measurements, because high resistance values often depend on applied voltage.

Figure 8 shows a different high-resistance measurement technique, using a constant current passing through the resistance to be measured. The resulting voltage across the resistance is then measured by an electrometer, a high-resistance voltmeter. These techniques are also often used for measuring semiconductor I vs. V characteristics and for measuring breakdown voltage curves.

Typical multifunction electrometers designed for these measurements can measure resistances up to $2\times10^{14}\Omega$, low currents down to 10^{-15}A, voltages up to 200V with input resistances greater than $10^{14}\Omega$, and charge to 10^{-14}C.

Shunt resistance in high-resistance measurements is usually limited by the resistance of the cabling and interconnection hardware. The resistance of particular insulators that may contribute to this shunt resistance depends on insulator surface conditions, moisture content, and temperature. For example, ceramic insulators cleaned with methanol which have not been touched may have $10^{14}\Omega$ or $10^{15}\Omega$ resistance. But these same insulators may degrade to $10^{11}\Omega$ or $10^{12}\Omega$ if they develop hairline cracks or if they accumulate a surface film such as that acquired from sitting in a dirty atmosphere for months.

Typical resistance values of various insulating materials are shown in **Figure 9**. Absorbed moisture may also change the resistance of certain insulators by orders of magnitude. A qualitative description of water absorption, piezoelectric, and triboelectric properties of various insulators is given in **Table 1**.

Guarding and Capacitive Effects

To minimize shunt currents, most electrometer amplifiers include a guard connection to their amplifier outputs. This guard connection makes the voltage drop across insulators located between the input and the guard equal to the output voltage divided by the amplifier gain, thus reducing the voltage stress across the insulator to nearly zero.

One additional source of error in high-resistance measurements is capacitance normally associated with cables and connectors. At high resistance levels, even a few picofarads of capacitance can create appreciable time constants. For example, a $10^{12}\Omega$ resistance and a cable capacitance of 100pF has an RC time constant of 100 seconds. However, use of guarding and feedback techniques will reduce this capacitance. Amplifier gain is normally in the range of 10^4 to 10^6. The effective input capacitance will be the unfedback input capacitance divided by this value.

FIGURE 8: High Resistance Measurement Using Constant Voltage or Constant Current Method

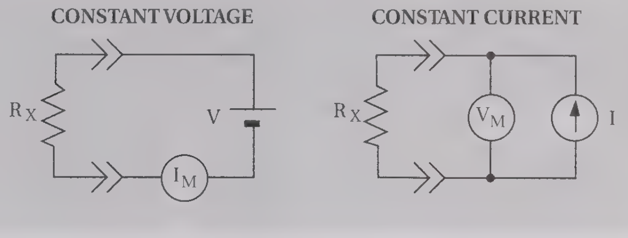
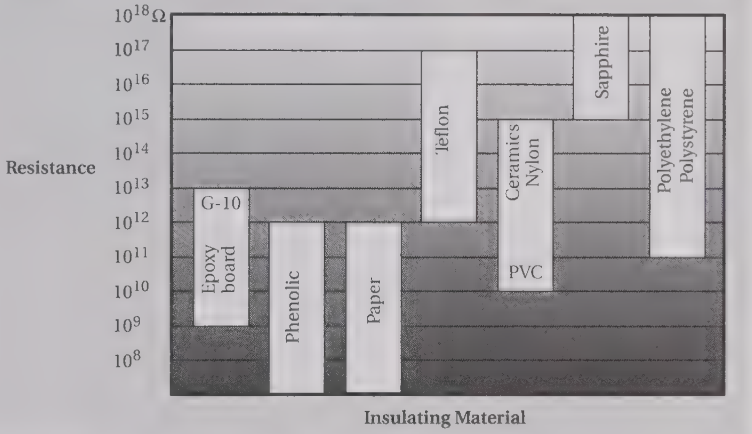


FIGURE 9: Approximate Resistances of Various Insulating Materials



SUMMARY

The feedback ammeter circuit used in electrometers and picoammeters reduces errors in low current measurements by reducing the voltage drop at the ammeter, which also reduces voltage stress on the interconnecting cabling and measurement time constant. If sources of unwanted generated currents due to triboelectric, piezoelectric, electrochemical, and Johnson noise phenomena are understood, they can be reduced to acceptable levels. High resistance measurements can be made using either constant-voltage or constant-current methods; the 617 electrometer can use either method.

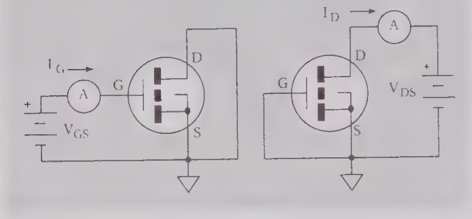
TABLE 1

		PROPERTY		
Volume Resistivity (Ohm-cm)	Material	Resistance to Water Absorption	Minimal Piezoelectric Effects	Minimal Triboelectric Effects
10^{16}— $10^{18}\Omega$	Sapphire	+	+	0
10^{17}— $10^{18}\Omega$	Teflon®	+	–	
10^{14}— $10^{18}\Omega$	Polyethylene	0	+	0
10^{12}— $10^{18}\Omega$	Polystyrene	0	0	–
10^{17}— $10^{18}\Omega$	Kel-F®	+	0	–
10^{12}— $10^{14}\Omega$	Ceramic	–	0	+
10^{12}— $10^{14}\Omega$	Nylon	–	0	–
10^{10}— $10^{17}\Omega$	Glass Epoxy	–	0	–
10^{10}— $10^{15}\Omega$	PVC	+	0	0
10^{5}— $10^{12}\Omega$	Phenolic		+	+

KEY: + Material very good in regard to the property.
0 Material moderately good in regard to the property.
– Material weak in regard to the property.

ELECTROMETER/PICOAMMETER APPLICATIONS

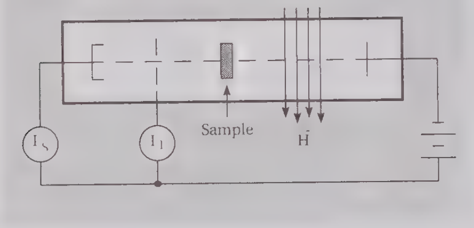
FIGURE 10: Measuring FET Gate Leakage and Channel Currents



Measuring FET Gate Leakage and Channel Current (Figure 10)

It is often important to measure gate leakage or channel leakage in MOSFETs, JFETs, analog switches, multiplexer circuits, and other circuits. Electrometers can measure sensitive levels of current, voltage, or charge in these tests. In the circuits shown, either a Model 617 electrometer or a Model 487 picoammeter may be used—each has a built-in voltage source.

FIGURE 11: Beam Experiments

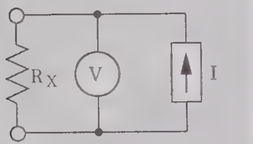


Beam Experiments (Figure 11)

Sensitivity and precision are vital for a variety of beam experiments and will enhance the performance of mass spectrometers, electron microscopes, and other analytical equipment involving beams of charged particles. The sensitivity of electrometers and picoammeters makes them especially useful in these experiments.

The same characteristics are needed for other measurements of charge, charge flow, and related phenomena in the research lab, such as ionization currents, ion chamber outputs, dielectric absorption in insulators, thermally induced currents, radiation studies, etc.

FIGURE 12: Resistance Measurement Using a Current Source



V is measured. Electrometer display indicates:

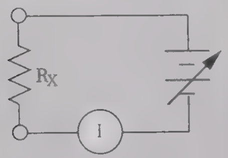
$R = \frac{V}{I}$ ohms

Resistance Measurement Using A Constant Current Source (Figure 12)

This is the simplest form of resistance measurement. Merely connect the resistance to the input and the electrometer displays the value. Test currents are selected with the OHMS range selection. The voltage across the resistor is read directly at the display or bus output.

A Model 220 I source and an electrometer in the VOLTAGE mode may be used for this measurement, providing more selectability of the I source.

FIGURE 13: Resistance Measurement Using a Voltage Source



I is measured. 617 or 487 displays V/I ohms.

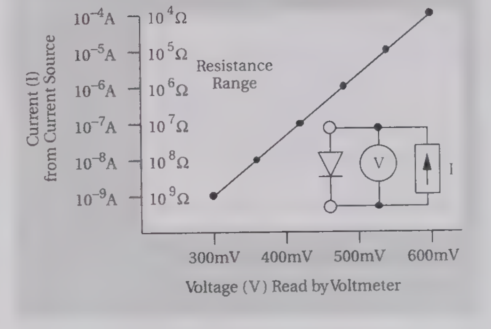
Resistance Measurement Using A Voltage Source (Figure 13)

In this mode, the test voltage is controlled by the 617's programmable V source or by the 487's programmable V source. Since high resistance values are often quite dependent on the impressed stress voltage, voltage control can be crucial to obtaining valid data. The 617 V source may be selected over the range of ±100V in 50mV steps, and the 487's V source outputs up to ±500V with 10mV increments.

I-V Curve: Source I, Read V (Figure 14)

The OHMS function of electrometers is a current source and a high-impedance voltmeter. It may be used to directly determine I-V characteristics, using decade current steps. A Model 220 I source may be used to provide settability from 0.5pA/step.

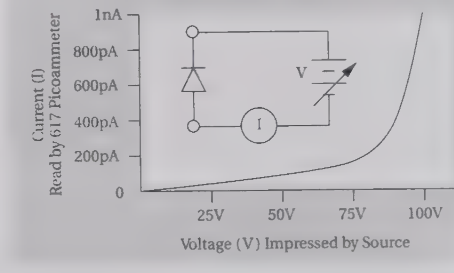
FIGURE 14: I-V Curve: Source I, Read V



I-V Curve: Source V Read I (Figure 15)

The AMPS mode of the 617 electrometer may be used in conjunction with its programmable V source, or a 487 picoammeter may be used in conjunction with its programmable V source, to develop a detailed I-V characteristic. Either directly on the display or via the IEEE-488 bus, you set the source to the desired voltage and read the current. The 617's voltage source goes to 100V in 50mV steps; the 487 provides up to 500V with 10mV settability.

FIGURE 15: I-V Curve: Source V, Read I



Electrometer/Source

617

617 PROGRAMMABLE ELECTROMETER
1.6 170 PA
STATUS
TALK
LISTEN
REMOTE
V-SOURCE
DATA STORE
ON/OFF
RECALL EXIT
PROGRAM
SELECT EXIT
POWER
ON
OFF
MAX INPUT

- Built-in V source
- Full autoranging
- Built-in IEEE-488 interface
- Built-in V-Ω Guard
- Data storage

IEEE-488

[illegible]

617
Electrometer/Source with Model 6011 Triax to Alligator Clip Input Cable

617-HIQ
Electrometer/Source with extended charge measurement range and Model 6011 Triax to Alligator Clip Input Cable

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

[illegible]

PROBE	
6103C	Voltage Divider Probe (1000:1) (requires 6012 adapter)
CABLES	
6011	Input Leads, triax to clips, 1.5m (5 ft.)
6011-10	Input Leads, triax to clips, 3m (10 ft.)
7024-3	Triaxial Cable, 0.9m (3 ft.)
7024-10	Triaxial Cable, 3m (10 ft.)
ADAPTERS	
6012	Triaxial to Coaxial UHF Adapter
6146	Triax Tee Adapter
6147	Male Triax to Female BNC Adapter
6171	3-Slot Male to 2-Lug Female Triaxial Adapter
6172	2-Slot Male to 3-Lug Female Triaxial Adapter
7023	Female Triaxial Bulkhead Connector
TEST FIXTURES	
6105	Resistivity Chamber
8002A	Guarded High Resistance Test Fixture
RACK MOUNT KITS	
1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

See page 163 for descriptions of all accessories.

The Model 617 Programmable Electrometer is our latest and most advanced electrometer. It is a sensitive, versatile, 4½-digit, 7-function instrument which includes a bipolar 100V voltage source, a decade current source, IEEE-488 interface, and outstanding low current accuracy specifications.

The 617 can measure resistances or generate I-V curves using either of two measurement techniques. Using the 1nA to 100μA decade current source, a known constant current is forced through the unknown resistance (see **Figure 12** on page 52). The developed voltage is measured with a high input impedance voltmeter, and the resistance or voltage is displayed and transmitted over the IEEE-488 bus. Alternately, the 617's programmable voltage source is applied across the unknown resistance and the resulting current is detected by the 617's sensitive current circuitry (see **Figure 13** on page 52). Current may be displayed directly, or resistances as high as $10^{16}\Omega$ can be directly measured; the 617 can calculate and display the quantity V/I. Since the resistance of most high resistance materials is a function of the applied voltage, the controlled voltage technique provides better characterization of these materials.

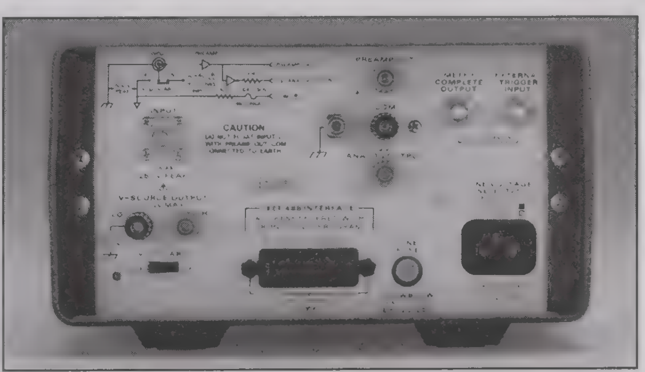
The 617's built-in IEEE-488 interface makes all controls programmable. You get full autoranging over the full span of ranges on voltage, current, charge, and resistance functions. And you can choose your format for the front panel readout: either exponential or engineering units. The JFET input gives you lower voltage noise and more immunity to overload, without sacrificing current sensitivity.

Pushbutton suppression lets you make relative measurements with respect to a selected baseline, or cancel background signals. ZERO CORRECT cancels internal offsets at the touch of a button. Both are bus programmable.

The built-in V-Ω GUARD switch lets you drive the inner shield of the triaxial input cable at guard voltage, minimizing leakage current and time constants. 100-point data storage is also built in, with Min/Max readings available from front panel or bus.

For all its precision and performance, the 617 is extremely easy to operate. Its DMM-like controls and clear 4½-digit display let you handle a variety of applications quickly and easily. And, like a DMM, the 617 features simple Digital Calibration. It also has real-time input and output triggers for communication with other instrumentation.

The unprecedented performance of the 617 makes it the ideal instrument for all of your sensitive measurement needs.



617 Electrometer/Source

OHMS RANGE	RESOLUTION	ACCURACY* (1 Year.) 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C	TEST CURRENT ±1.5%
2 kΩ	100 mΩ	0.20 + 4	0.01 + 3	100 μA
20 kΩ	1 Ω	0.15 + 1	0.01 + 0.3	100 μA
200 kΩ	10 Ω	0.25 + 1	0.01 + 0.3	10 μA
2 MΩ	100 Ω	0.25 + 1	0.02 + 0.3	1 μA
20 MΩ	1 kΩ	0.25 + 1	0.02 + 0.3	100 nA
200 MΩ	10 kΩ	0.30 + 1	0.02 + 0.3	10 nA
2 GΩ	100 kΩ	1.5 + 1	0.04 + 0.3	1 nA
20 GΩ	1 MΩ	1.5 + 1	0.04 + 0.1	1 nA
200 GΩ	10 MΩ	1.5 + 1	0.04 + 0.1	1 nA

*When properly zeroed.

MAXIMUM OPEN CIRCUIT VOLTAGE: 300V DC.

PREAMP SETTLING TIME (To 0.1% of final reading with <100pF input capacitance): 2kΩ through 20MΩ: 15ms; 200MΩ: 150ms. **(To 1% of final value with Input Guard on and <1pF of unguarded input capacitance):** 2GΩ: 10ms; 20GΩ: 100ms; 200GΩ: 1s.

V/I MODE: Used with V source; displays resistance (5×10^4 to $10^{16}\Omega$) calculated from measured current. V/I Ohms accuracy equal to accuracy of V source plus accuracy of selected amps range.

VOLTAGE SOURCE

OUTPUT: –102V to +102V in 50mV steps.

ACCURACY (1 Yr., 18°–28°C): ±(0.2% + 50mV).

TEMPERATURE COEFFICIENT: ±(0.005% + 1mV)/°C

MAXIMUM OUTPUT CURRENT: ±2mA; active current limit at <4mA with annunciation.

SETTLING TIME: <3ms to rated accuracy.

NOISE: <(1ppm of output voltage + 200μV) p-p from 0.1Hz to 10Hz.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Function, Range, Zero Check, Zero Correct, Zero Suppress, EOI, Trigger, Terminator, 100-Reading Storage and Retrieval, Calibration, V Source Output, Display Format, SRQ, Status (including V Source I-Limit), Output Format.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

TRIGGER TO READING DONE: 350ms typical.

GENERAL

DISPLAY: 4½-digit numeric LEDs with appropriate decimal point and polarity indication; signed two-digit alphanumeric exponent.

OVERRANGE INDICATION: Display reads "OL".

RANGING: Automatic or manual.

CONVERSION TIME: 330ms.

DATA STORE and MIN/MAX: 100-reading store capacity; records data at one of six selectable rates from every reading to 1 reading/hour, or by manual triggering. Also detects and stores maximum and minimum readings continuously while in the Data Store mode.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

MAXIMUM INPUT: 250V peak, DC to 60Hz sine wave; 10s per minute maximum on mA ranges.

MAXIMUM COMMON MODE VOLTAGE (DC to 60Hz sine wave): Electrometer, 500V peak; V Source, 100V peak.

ISOLATION (Input LO to chassis): Typically $10^{10}\Omega$ in parallel with 500pF.

INPUT CONNECTOR: Two lug triaxial on rear panel.

OUTPUT CONNECTORS: 5-way binding posts on rear panel for V source, preamp, and analog outputs. Rear panel BNC for External Trigger and Meter Complete.

2V ANALOG OUTPUT: 2V for full range input. Inverting in Volts and Ohms modes. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Volts and Ohms measurements. Can be used as an inverting output or with external feedback in Amps and Coulombs modes. Output impedance 100Ω.

GAIN ERROR AT PREAMP OUTPUT: Typically 5ppm.

SMALL SIGNAL BANDWIDTH AT PREAMP OUTPUT: Typically –3dB at 100kHz.

EXTERNAL TRIGGER: TTL compatible External Trigger and Electrometer Complete.

V, Ω GUARD SWITCH: OFF position: Inner shield of triax is Input LO, input capacitance is ≤20pF. ON position: Inner shield of triax is Guard (follows input HI). Input capacitance is ≤2pF. Use Analog Output COM for Input LO connection.

ENVIRONMENT: Operating: 0°-50°C; relative humidity 70% non-condensing, up to 35°C. **Storage:** –25° to +65°C.

SHIELDING: Double shielded.

WARM-UP: 2 hours to rated accuracy (see manual for recommended procedure).

POWER: 105–125V or 210–250V (internal switch selected), 90–110V available; 50–60Hz, 25VA.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide ×359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.6kg (8 lbs.).

VOLTS RANGE	RESOLUTION	ACCURACY (1 Year)* 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
200 mV	10 μV	0.05 + 4	0.004 + 3
2 V	100 μV	0.05 + 1	0.004 + 0.3
20 V	1 mV	0.05 + 1	0.005 + 0.1
200 V	10 mV	0.07 + 1	0.007 + 0.1

*When properly zeroed.

NMRR: >80dB on 200mV, 60dB on 2V and 20V, 55dB on 200V range, at 50Hz or 60Hz ±0.1%.

CMRR: >120dB at DC, 50Hz or 60Hz.

INPUT IMPEDANCE: >200TΩ in parallel with 20pF (<2pF guarded).

GAIN ERROR AT PREAMP OUTPUT: Typically 5ppm.

SMALL SIGNAL BANDWIDTH AT PREAMP OUTPUT: Typically 100kHz (–3dB).

AMPS RANGE	RESOLUTION	ACCURACY (1 Year)* 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
2 pA	100 aA	1.6 + 66	0.15 + 8
20 pA	1 fA	1.6 + 7	0.15 + 1
200 pA	10 fA	1.6 + 1	0.15 + 0.1
2 nA	100 fA	0.25 + 5	0.015 + 3
20 nA	1 pA	0.25 + 1	0.015 + 0.3
200 nA	10 pA	0.25 + 1	0.015 + 0.1
2 μA	100 pA	0.15 + 4	0.005 + 3
20 μA	1 nA	0.15 + 1	0.005 + 0.3
200 μA	10 nA	0.15 + 1	0.006 + 0.1
2 mA	100 nA	0.15 + 4	0.005 + 3
20 mA	1 μA	0.15 + 1	0.005 + 0.3

*When properly zeroed using recommended warm-up procedure.

INPUT BIAS CURRENT: <5fA at 23°C

INPUT VOLTAGE BURDEN: <1mV except 3mV on 20mA range.

PREAMP SETTLING TIME (to 1% of final value): 2.5s on pA, 15ms on nA, 5ms on μA and mA ranges.

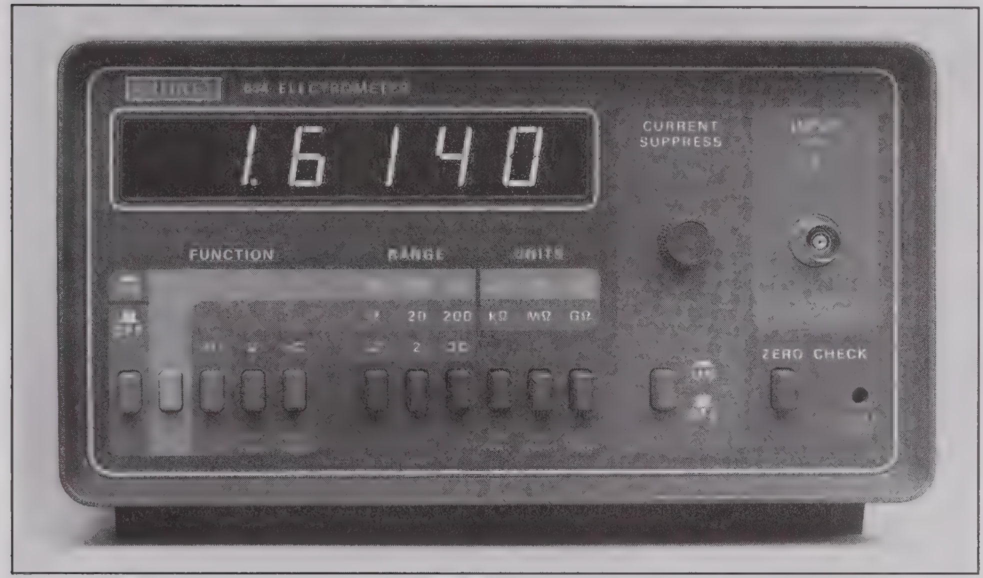
NMRR: >95dB on pA, 60dB on nA, μA, and mA ranges at 50Hz or 60Hz ±0.1%.

COULOMBS (617) RANGE	RESOLUTION	ACCURACY* (1 Year) 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
200 pC	10 fC	0.4 + 4	0.02 + 3
2 nC	100 fC	0.4 + 1	0.02 + 0.3
20 nC	1 pC	0.4 + 1	0.02 + 0.1
(617-HIQ)			
200 nC	10 pC	2.0 + 4	0.04 + 3
2 μC	100 pC	2.0 + 1	0.04 + 0.3
20 μC	1 nC	2.0 + 1	0.04 + 0.1

*When properly zeroed.

INPUT BIAS CURRENT: <5fA at 23°C.

Electrometer 614



614 ELECTROMETER
1.6140
CURRENT SUPPRESS
FUNCTION
RANGE
UNITS
20
200
kΩ
MΩ
GΩ
2
20
ZERO CHECK

- 10^{-14}A sensitivity
- Current suppression
- $5 \times 10^{13}\Omega$ input impedance
- 4½-digit LED display

The Model 614 is an optimum synthesis of careful design, basic simplicity, quality components, and pragmatic performance capabilities. It makes the difficult job of sensitive measurements as easy as operating a DMM, yet it is extremely sensitive and affordable.

Pushbutton Easy

The handsome appearance of the 614 is an example of form following function. The pushbutton configuration is precise, simple, quick, and easy to use. Color-coded range and function selection is as functional as it is attractive. The front panel is designed to be legible with a large 4½-digit LED display and clear legends for all functions.

Battery/Line

For isolation from AC line interference, the 614 features a built-in, rechargeable lead-acid battery pack. The pack provides over 10 hours of off-line operation, automatically recharges when the power line is plugged in, and automatically cuts in should line power be interrupted.

Flexible & Convenient

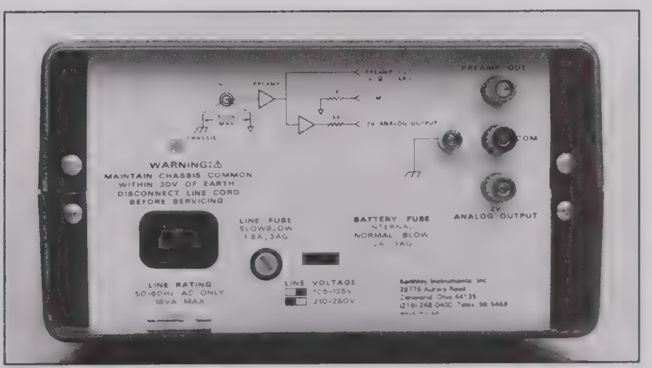
The 614 rear panel includes two analog outputs: a 2V output for recorders and a preamp output for use as a driven guard with the 6167 guarded input adapter. The CURRENT SUPPRESS feature allows background currents to be zeroed out at the touch of a button. Durable construction and a full range of capabilities assure a long and cost-effective life cycle.

Sensitive Performer

The 614 performs four functions: current, resistance, voltage, and charge measurements. It is capable of detecting currents as low as 10^{-14}A and resistances up to $2 \times 10^{11}\Omega$. It provides more than $5 \times 10^{13}\Omega$ input impedance on the voltage ranges, and can detect charge over a range of 10^{-14} to 2×10^{-8}C. It is appropriate for a wide range of applications in component and circuit testing as well as in research and student laboratories.

Budgetable

Our optimal design approach to the Model 614 allowed us to reduce production costs without sacrificing the sophisticated performance capabilities traditional with electrometers. The combination of modern components and assembly techniques, as well as high reliability based on a JFET front end, keep the cost of the Model 614 low and assure a high return on your investment.



PREAMP
PREAMP OUT
2V ANALOG OUTPUT
CHASSIS
COM
WARNING: ⚠
MAINTAIN CHASSIS COMMON
WITHIN 30V OF EARTH
DISCONNECT LINE CORD
BEFORE SERVICING
LINE FUSE
SLOWBLOW
1/8A, 3AG
BATTERY FUSE
INTERNAL
NORMAL BLOW
3AG
2V
ANALOG OUTPUT
LINE RATING
50-60Hz AC ONLY
18VA MAX
LINE VOLTAGE
105-125V
210-250V
Keithley Instruments Inc
28775 Aurora Road
Cleveland Ohio 44139
(216) 248-0400 Telex 98 5469

[illegible]

614
Electrometer with Model 6011 Triax to Alligator Clips Input Cable

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

PROBE	
6103C	Voltage Divider Probe (1000:1) (requires 6012 adapter)
CABLES	
6011	Input Leads, triax to clips, 1.5m (5 ft.)
6011-10	Input Leads, triax to clips, 3m (10 ft.)
7024-3	Triaxial Cable, 0.9m (3 ft.)
7024-10	Triaxial Cable, 3m (10 ft.)
ADAPTERS	
6012	Triaxial to Coaxial UHF Adapter
6146	Triax Tee Adapter
6147	Male Triax to Female BNC Adapter
6167	Guarded Input Adapter
6171	3-Slot Male to 2-Lug Female Triaxial Adapter
6172	2-Slot Male to 3-Lug Female Triaxial Adapter
7023	Female Triaxial Bulkhead Connector
TEST FIXTURES	
6105	Resistivity Chamber
8002	Guarded High Resistance Test Fixture
RACK MOUNT KITS	
1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

See page 163 for descriptions of all accessories.

614 Electrometer

VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°–28°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg + counts)/°C
200 mV	10 µV	0.08 + 2*	0.005 + 2
2 V	100 µV	0.08 + 2	0.005 + 0.2
20 V	1 mV	0.08 + 1	0.005 + 0.1

*When properly zeroed.

NMRR: >60dB at 50Hz and 60Hz.

CMRR: >120dB at DC, 50Hz and 60Hz.

INPUT IMPEDANCE: >5 × 10¹³Ω in parallel with 20pF.

MAXIMUM OVERLOAD: 350V peak.

COULOMBS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°–28°C ±(%rdg + counts)
200 pC	10 fC	5 + 50
2 nC	100 fC	5 + 5
20 nC	1 pC	5 + 1

INPUT BIAS CURRENT: <60fA at 23°C.

MAXIMUM OVERLOAD: 350V peak.

AMPS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(rdg+counts)/°C	MAXIMUM SUPPRESSION
20 pA	10 fA	1.5 + 5*	0.1 + 1	± 20 pA
200 pA	100 fA	1.5 + 3	0.1 + 0.3	±200 pA
2 nA	1 pA	1.5 + 1	0.1 + 0.3	±200 pA
20 nA	10 pA	0.5 + 2	0.02 + 0.3	± 20 nA
200 nA	100 pA	0.5 + 1	0.02 + 0.3	±200 nA
2 µA	1 nA	0.5 + 1	0.02 + 0.3	±200 nA
20 µA	10 nA	0.3 + 2	0.01 + 0.3	± 20 µA
200 µA	100 nA	0.3 + 1	0.01 + 0.3	±200 µA
2 mA	1 µA	0.3 + 1	0.01 + 0.3	±200 µA

*When properly zeroed.

INPUT BIAS CURRENT: <60fA at 23°C.

INPUT VOLTAGE BURDEN: <200µV.

PREAMP SETTLING TIME (to 1% of final value): 0.6s on pA, 5ms on nA, 2.5ms on µA ranges.

NMRR: 70dB on pA and nA ranges; 55dB on µA and mA ranges. At 50Hz and 60Hz.

MAXIMUM OVERLOAD: 350V peak on pA and nA ranges; 75V peak on µA and mA ranges.

GENERAL

DISPLAY: Five LED digits with appropriate decimal point, polarity, and overload indication.

CURRENT SUPPRESS: Active in Current mode; allows correction for input currents on any given range.

CONVERSION TIME: 400ms.

2V ANALOG OUTPUT: 2V out for full range input. Inverting in Voltage and Resistance modes. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Voltage and Resistance measurements. Can be used as an inverting output or with external feedback in Current and Coulombs modes. Output impedance 1kΩ.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

CONNECTORS: Input: 2-lug triax. **Output:** 5-way binding posts.

ENVIRONMENT: Operating: 0°–35°C, up to 70% relative humidity. **Storage:** –25° to +65°C.

POWER: Line or battery operated. 105–125V or 210–250V (switch selected), 90–110V available. 50–60Hz, 5VA typical; 18VA maximum during battery charge. 10 hour operation from full charge, 20 hours to recharge.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.3kg (7.2 lbs.).

OHMS

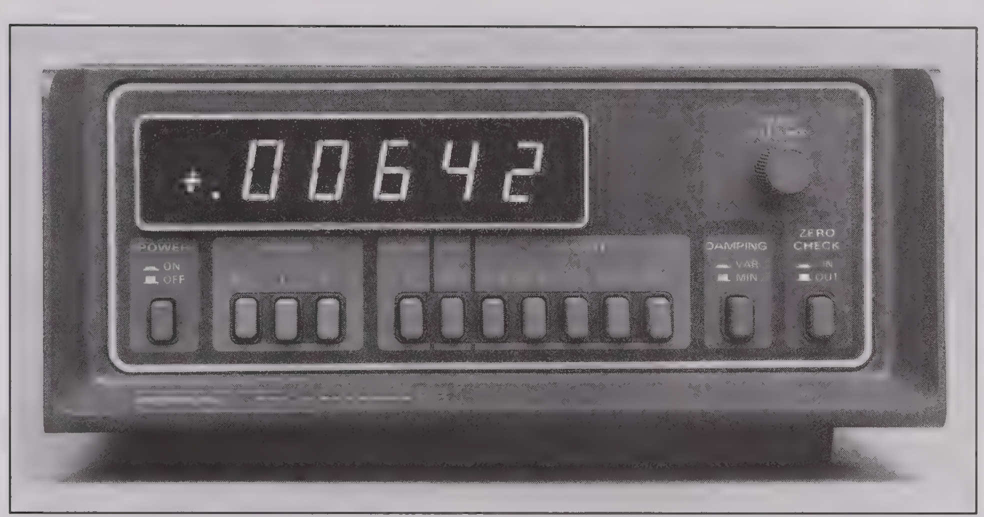
RANGE	RESOLUTION	ACCURACY (1 Year) 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C	TEST CURRENT
2 kΩ	1 Ω	0.5 + 2	0.03 + 0.3	100 µA
20 kΩ	10 Ω	0.5 + 2	0.03 + 0.3	100 µA
200 kΩ	100 Ω	0.5 + 2	0.03 + 0.3	10 µA
2 MΩ	1 kΩ	0.8 + 2	0.04 + 0.3	100 nA
20 MΩ	10 kΩ	0.8 + 2	0.04 + 0.3	100 nA
200 MΩ	100 kΩ	0.8 + 2	0.04 + 0.3	100 nA
2 GΩ	1 MΩ	2.0 + 3	0.12 + 0.3	100 pA
20 GΩ	10 MΩ	2.0 + 2	0.12 + 0.3	100 pA
200 GΩ	100 MΩ	2.0 + 2	0.12 + 0.3	100 pA

MAXIMUM OPEN CIRCUIT VOLTAGE: 32V DC.

MAXIMUM OVERLOAD: 75V peak on kΩ ranges; 350V peak on MΩ and GΩ ranges.

Electrometer

642



The Keithley 642 is a direct-reading MOSFET-based electrometer for sensitive measurement of current, voltage, or charge. Its current measurement range is 10aA to 200nA with typically less than 1mV voltage burden. Voltage reading capabilities are 10µV to 10V with 10,000TΩ input resistance. Charge can be measured from 800aC to 100pC. Maximum sensitivity is obtained when using the charge mode to integrate current applied to the input.

High Resolution

The digital format permits observation of small changes in large signals with resolution to 1 part in 20,000 at the digital display. The FEEDBACK output has low noise and non-linearity of only about 5ppm. This wide dynamic range (from noise level to maximum output) provides constant gain over the full span, and eliminates the need for range changing.

State-of-the-Art Design

The 642 uses a specially packaged dual monolithic MOSFET with compensated temperature coefficient in a guarded package. Variations in ambient temperature do not cause significant errors because compensation circuitry is individually adjusted for each FET to give a voltage coefficient of only 30µV/°C.

In the design of the remote head, the active input volume has been minimized. Less than 15 ionization current pulses per hour are observed.

The preamplifier is a direct-coupled circuit with a single, well-controlled time constant. It is a first-order system which produces an exponential response to step inputs. Response time can be varied over a 100:1 span on the 10^{-12}A range.

The remote head is sealed and contains desiccant paper to maintain low internal humidity. Internal humidity can be observed on an indicator on the bottom of the remote head.

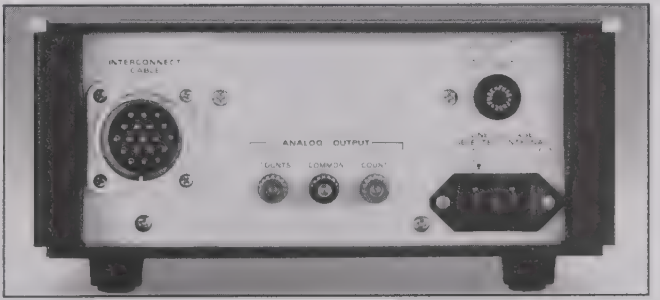
The ZERO CHECK switching mechanism has been designed for minimum charge transfer, typically less than 10fC. Internal adjustments may be used to further compensate the average charge transfer.

Analog Outputs

Three analog outputs are provided: The FEEDBACK output on the remote head has the most precision and widest dynamic range (over 10^5), lowest noise, and fastest speed. The 1V/10,000 COUNTS output on the rear of the mainframe normalizes the output to 1V per 10,000 counts regardless of range. The 1V/100 COUNTS output (also on the rear panel) is useful in sensitive measurements to amplify the signal so that 1V corresponds to 100 counts.

Accessories

Input connections are described on the Input Connection Chart. In addition, an isolated BCD output option (Model 6422), IEEE-488 output (Model 6423), 12V battery adapter (Model 6428), and individually sealed desiccant paper refills (Model 6421) are available.



- 10^{-17}A (10aA) sensitivity
- Over 100,000:1 linear dynamic range at analog output
- Fast response: 22ms time constant on 10^{-10}A range

IEEE-488

[illegible]

642
Electrometer with 4-ft. interconnect cable and remote head

642 LNFPA
Electrometer (<50µV p-p noise, fast current measurement capabilities) with 4-ft. interconnect cable and remote head

642 LNFPA/6423
Electrometer (<50µV p-p noise, fast current measurement capabilities) with IEEE-488 Output, 4-ft. interconnect cable and remote head

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

[illegible]

OUTPUTS	
6422	Isolated BCD Output
6423	Isolated IEEE-488 Output
ADAPTERS	
6424	BNC Input Adapter
6425	GenRad GR874® Air Line Input Adapter
6428	Battery Adapter
CABLES	
4801	Low Noise BNC Input Cable, 4 ft.
6427-20	Interconnect Cable, 20 ft.
6427-50	Interconnect Cable with Remote Supply, 50 ft.
TEST FIXTURE	
6426	Sapphire Insulated Test Box
RACK MOUNT KIT	
2000	Single Fixed Rack Mount Kit
OTHER	
6421	Desiccant Paper Refill

See page 163 for descriptions of all accessories.

642 Electrometer

[illegible]

[illegible]	[illegible]	[illegible]
10^{-8} A	0.19999×10^{-8} A	10.9999×10^{-8} A
10^{-10} A	0.19999×10^{-10} A	10.9999×10^{-10} A
10^{-11} A	0.19999×10^{-11} A	10.9999×10^{-11} A
10^{-12} A	0.19999×10^{-12} A	10.9999×10^{-12} A

[illegible]	[illegible]	[illegible]
10^{-8} A	1 + 3	< 40 ms
10^{-10} A	1 + 3	≤100 ms
10^{-11} A	1.3 + 3	≤400 ms
10^{-12} A	1.5 + 6	≤ 5 ms

NOISE: 4×10^{-17}A rms (2×10^{-16}A p-p); <15 self-generated alpha pulses per hour.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
0.1 V	.19999	0.5 + 3	3 s
1 V	1.9999	0.05 + 1	0.3 s
10 V	10.999	0.05 + 1	0.03 s

NOISE: <20μV rms (100μV p-p).

ZERO STABILITY: 24 hours, ±3°C: ±180μV.

TEMPERATURE COEFFICIENT OUTSIDE OF ±3°C SPAN: ±(30μV + 0.5 count)/°C.

INPUT RESISTANCE: $10^{16}\Omega$.

COULOMBS

RANGES: 10^{-11} coulombs, 0.1, 1, or 10 ranges.

INPUT CURRENT (23°C ±1°C): $<5 \times 10^{-17}$A.

ACCURACY (23°C ±1°C for 6 months, exclusive of noise): ±(0.3% + 5 counts).

NOISE: 8×10^{-16} coulombs rms (4×10^{-15} coulombs p-p), 0.1 range; <15 self-generated alpha pulses per hour.

CHARGE ERROR DUE TO ACTUATION OF ZERO CHECK: Typically $<10^{-14}$ coulombs.

GENERAL

MAXIMUM INPUTS: Normal or Common Mode: 30V rms, DC to 60Hz.

DISPLAY: Five 0.5 in. LED digits with decimal point and polarity indication.

CONVERSION PERIOD FOR DIGITAL DISPLAY: 400ms.

ANALOG OUTPUTS: Two analog outputs are provided on mainframe rear panel: 1V/10,000 counts and 1V/100 counts of the digital display.

POWER REQUIREMENTS: 90–110V, 105–125V, 120–220V, or 210–250V; 50Hz to 60Hz, 30VA maximum.

DIMENSIONS, WEIGHTS:

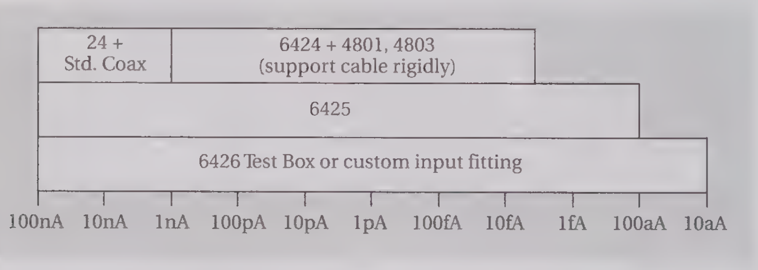
Mainframe: 3½ in. half rack, 100mm high × 217mm wide × 308mm deep (4 in. × 8½ in. × 12⅛ in.). Net weight 2.9kg (6 lbs., 6 oz.).

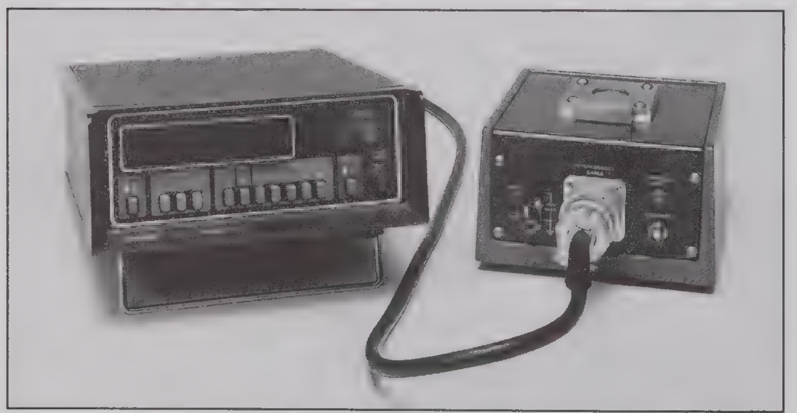
Remote Head: 102mm high × 162mm wide × 165mm deep (4 in. × 6⅜ in. × 6½ in.), exclusive of connectors. Net weight 4.1kg (9 lbs., 2 oz.).

Interconnect Cable: 4 ft. long. Net weight 0.6kg (1 lb., 3 oz.).

ACCESSORY SUPPLIED: Four-foot remote head to mainframe interconnect cable.

Input Connection Chart, showing recommended input connections for various current sensitivities.





642 Remote Head is sealed and contains desiccant paper to maintain low internal humidity.

642 LNFPA

In precision ratio isotope mass spectrometry, the sensitivity and linearity of the 642 are essential. However, the standard unit may not be fast enough to settle to within 0.01% of final value in the short time the beam remains stable. Also, precision requirements often demand lower noise per unit bandwidth to obtain sufficiently repeatable results.

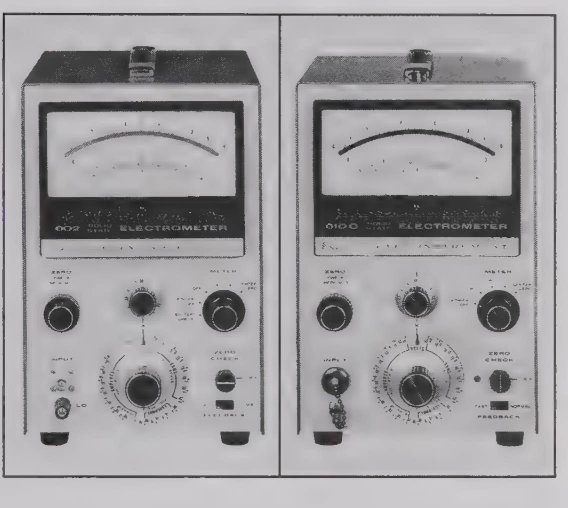
The 642 LNFPA was developed for these demanding situations. Typically, it will settle to within 0.01% of final value in 2 seconds or less on the 10^{-11}A range, allowing most of the time the beam is stable for integration of the signal from the precision FEEDBACK output. It also has a selected lower noise input FET. Noise is documented and <50μV p-p (vs. the standard 100μV p-p) in the VOLTAGE mode, reducing the effective noise current on the 10^{-11}A range.

Electrometers 602,610C

The battery-operated Model 602 and the line-operated Model 610C electrometers are analog instruments with a wide range of capabilities. The 610C is a grounded-input instrument which has wider voltage, resistance, and charge ranges, but the 602 adds battery-operated convenience and ±1500V off-ground capability.

Low input current of 5×10^{-15}A minimizes zero offset with high source resistances and permits maximum resolution when measuring current and charge.

To optimize measurement results under different conditions, two measuring modes are provided: shunt (NORMAL) which provides selectable input resistance on VOLTS, or feedback (FAST) which provides low input voltage as an ammeter or coulombmeter.



602:

- Battery operated: 1000 hours life
- 1500V floating capability
- 5×10^{-15}A input current
- Measures V, I, R, Q, and is a current source

610C:

- 5×10^{-15}A input current
- $10^{14}\Omega$ input resistance to 100V
- Measures V, I, R, Q, and is a current source

ORDERING INFORMATION

602
Solid State Battery Operated Electrometer with Model 6011 Input Cable and Mating Output Connector

610C
Solid State Line Operated Electrometer with Mating Input and Output Connectors

These products are available with an **Extended Warranty.** See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

AS VOLTMETERS

RANGE:
602: 0.001V full scale to 10V in nine 1× and 3× ranges.
610C: 0.001V full scale to 100V in eleven 1× and 3× ranges.

ACCURACY: ±1% of full scale on all ranges, exclusive of noise and drift.

ZERO DRIFT: <1mV per 24 hours; <150μV per °C.

METER NOISE: ±25mV max. with input shorted on most sensitive range.

INPUT IMPEDANCE: $>10^{14}\Omega$ shunted by 20pF. Input resistance may also be selected in decade steps from 10 to $10^{11}\Omega$.

AS AMMETERS

RANGE: 10^{-14}A full scale to 0.3A in twenty-eight 1× and 3× ranges.

ACCURACY: ±2% of full scale on 0.3 to 10^{-11}A ranges using smallest available multiplier setting; ±4% of full scale on 3×10^{-12} to 10^{-14}A ranges.

METER NOISE: $<\pm 3 \times 10^{-15}$A.

OFFSET CURRENT: $<5 \times 10^{-15}$A.

AS AMPLIFIERS

INPUT IMPEDANCE: $>10^{14}\Omega$ shunted by 20pF. Input resistance may also be selected in decade steps from 10 to $10^{11}\Omega$.

UNITY GAIN OUTPUT: At DC, output = input within 10ppm, exclusive of noise & drift, for output currents ≤100μA. Up to 1mA may be drawn for input voltages ≤10V. Output polarity is the same as input polarity.

VOLTAGE RECORDER OUTPUT:
602: ±1V for full scale input. Internal resistance is 910Ω. Output polarity is opposite input polarity.
610C: ±3V for full scale input. Internal resistance is 3kΩ. Output polarity is opposite input polarity.

GAIN: 602: 0.1, 0.33, etc. to 1000.
610C: 0.3, 0.1, etc. to 3000.

FREQUENCY RESPONSE (within 3dB): DC to 40kHz at gain of 1 and lower, decreasing to DC to 100Hz at maximum gain. Full output response limited to 3kHz on any gain.

CURRENT RECORDER OUTPUT: ±1mA for full scale input, variable ±5% with 1400Ω recorders.

AS OHMMETERS

RANGE:
602: 100Ω full scale to $10^{13}\Omega$ in 23 linear 1× and 3× ranges.
610C: 100Ω full scale to $10^{14}\Omega$ in 25 linear 1× and 3× ranges.

ACCURACY:
602: ±3% of full scale on 100 to $10^{9}\Omega$ ranges using largest available multiplier setting; 5% of full scale on 3×10^{10} to $10^{13}\Omega$ ranges.

AS COULOMBMETERS

RANGE:
602: 10^{-13}C full scale to 10^{-6}C in fifteen 1× and 3× ranges.
610C: 10^{-13}C full scale to 10^{-5}C in seventeen 1× and 3× ranges.

ACCURACY: ±5% of full scale on all ranges. Drift due to offset current $\leq 5 \times 10^{-15}$C per second.

GENERAL

POLARITY: Meter switch selects left-zero (positive or negative) or center- zero scales. Output polarity is not reversed.

CONNECTORS:
Input (602): Teflon-insulated 2-lug triaxial.
Input (610C): Teflon-insulated UHF; ground binding post.
LO (602): Binding post.
Voltage or current output: Amphenol 80-PC2F.
Unity gain output, chassis ground: Binding posts.

POWER: 602: Six 2N6 (or 246, VS305, NEDA 1602); one RM-1W. 1000 hours battery life. Battery conditions may be checked at front panel.

610C: 105–125V or 210–250V (switch selected), 50–60Hz, 10W.

LINE STABILITY (610C): A 10% change in line voltage will cause <10μV meter deflection on all ranges.

DIMENSIONS, WEIGHT: 275mm high × 175mm wide × 290mm deep (10.75 in. × 7 in. × 11.5 in.). Net weight: **602**, 5.7kg (13 lbs.); **610C**, 4.8kg (11 lbs.).

ACCESSORIES SUPPLIED:
602: Model 6011 Input Cable, mating output connector.
610C: Mating input and output connectors.

ACCESSORIES AVAILABLE

PROBES

2503	Static Detector Probe (610C)
6103C	Voltage Divider Probe (1000:1)

CABLES

6011	Input Leads, Triax to Clips, 0.9m (3 ft.) (602)
6011 -10	Input Leads, Triax to Clips, 3m (10 ft.) (602)
19072	Coaxial Input Cable, UHF to Alligator Clips, 0.9m (3 ft.) (610C)
7024-3	Triaxial Input Cable, 0.9m (3 ft.) (602)
7024-10	Triaxial Input Cable, 3m (10 ft.) (602)

CONNECTOR (602)

7023	Female Triaxial Bulkhead Connector

ADAPTERS

6012	Triax to UHF Adapter (602)
6146	Triax Tee Adapter (602)
6147	Male Triax to Female BNC Adapter (602)
6167	Guarded Input Adapter (602)
6171	3-Slot Male to 2-Lug Female Triaxial Adapter (602)
6172	2-Slot Male to 3-Lug Female Triaxial Adapter (602)

TEST FIXTURES

6105	Resistivity Chamber
8002A	High Resistance Test Fixture with Cables

See page 163 for descriptions of all accessories.

486,487

Picoammeter, Picoammeter/Source

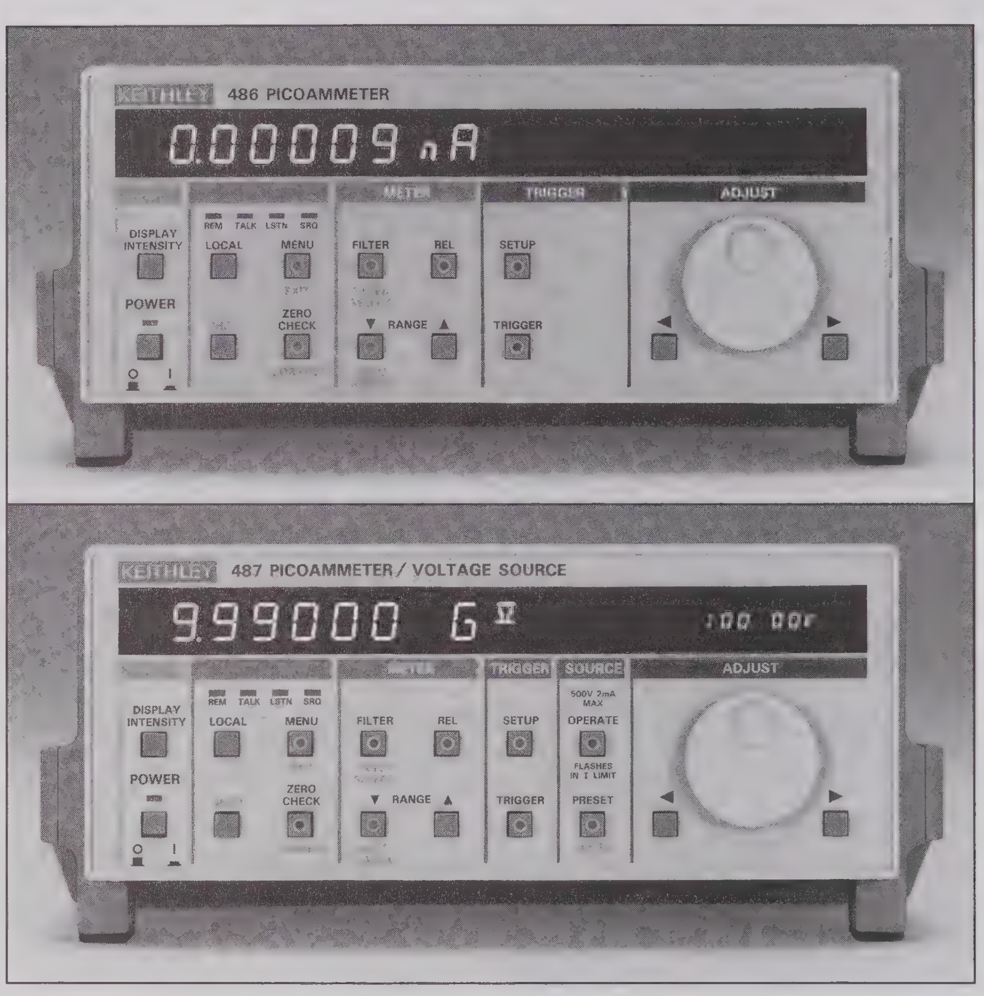
486:

- 10fA sensitivity
- 180 readings per second
- IEEE-488 interface

487:

- Resistivity measurements ($<1\Omega$ to $>10^{16}\Omega$)
- ± 500V source
- 10fA sensitivity
- 180 readings per second
- IEEE-488 interface

IEEE-488



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486
Picoammeter with 7078-ALG 3-Slot Triax to Alligator Clip Cable

487
Picoammeter/Voltage Source with 236-ILC-3 Interlock Cable, 7078-ALG 3-Slot Triax to Alligator Clip Cable

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CABLES	
7078-TRX-3	3-Slot Male Triax to 3-Slot Male Triax Cable, 0.9m (3 ft.)
ADAPTERS	
6171	3-Slot Male Triax to 2-Lug Female Triax
6172	2-Slot Male Triax to 3-Lug Female Triax
TEST FIXTURES	
8002A	Guarded High Resistance Test Fixture
8008	Resistivity Chamber
RACK MOUNTS	
4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit

See page 163 for descriptions of all accessories.

486 Picoammeter

The Model 486 is a 5½-digit autoranging picoammeter designed for low current applications where fast reading rates must be made. With a speed of 180 readings per second, the 486 is the fastest, most sensitive picoammeter in the industry.

The 486 is ideal for low level DC current applications, such as:

- PMT current measurements
- mass spectrometer current measurements
- probe current measurements in electrochemistry
- plasma generated currents
- ion chamber currents

Operation is fast and convenient. Selectable analog and digital filters provide optimum wideband performance with minimum noise. Autoranging selects the most appropriate range within 100ms. The measurement buffer holds up to 512 readings for fast data acquisition. Any reading within the buffer may be displayed, or the entire buffer may be searched for the maximum and minimum values.

Other important features include REL which allows measurements to be made relative to a selectable baseline. ZERO CHECK and CORRECT functions correct for voltage offset errors using front panel or software commands.

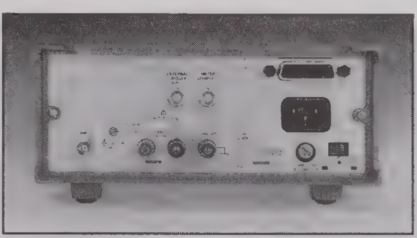
The IEEE-488 interface provides simple integration and convenient user interaction. Digital calibration can be accomplished over the bus or completely from the front panel. The display features three selectable intensities (bright, dim and off) for use in light-sensitive environments.

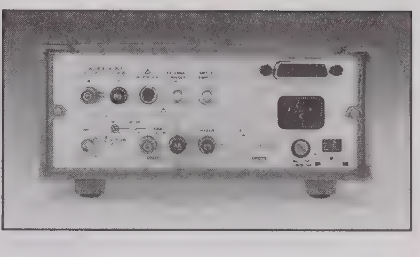
487 Picoammeter/Voltage Source

The Model 487 is designed for measurement of low current and very high resistances. This instrument incorporates all the capabilities of the 486, and adds a programmable ±500V source. This combination of picoammeter and voltage source provides a powerful high resistance meter and fast picoammeter in one instrument.

The 487 will make current measurements from 10fA to 2mA. Two voltage source ranges are available: a 500V range with 10mV resolution and a 50V range with 1mV resolution. A PRESET button allows the user to toggle between two separate source values.

Picoammeter, Picoammeter/Source 486,487





The 487 will source up to 500V, measure the current with 10fA sensitivity, and then instantly calculate the resistance value, from 500 mΩ to 5 × 10^{16}Ω. The unit will display either current or resistance. Reading intervals from 10ms to 1000s can be programmed, simplifying tests that require a predetermined "soak" time.

Two displays, one for current readings and one for voltage sourcing, permit the voltage setting and the measured current to be viewed throughout the measurement.

The Model 487 is the most effective test instrument for performing such tasks as resistivity, I-V measurements, component leakage, and insulation resistance. A common test procedure, written by the American Society of Testing and Materials, D257: D-C RESISTANCE OR CONDUCTANCE OF INSULATING MATERIALS is easily performed with the 487.

V/I OHMS (487 only)

Used with voltage source; resistance calculated from voltage setting and measured current. V/I OHMS accuracy equals voltage source accuracy plus ammeter accuracy. Typical accuracy better than 0.6% for readings between 1kΩ and 1TΩ.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters programmable except for IEEE-488 bus address and frequency for line integration.

TRIGGER TO FIRST BYTE: <50ms (trigger on TALK, ATN false to talker DAV true, G7 data format).

GENERAL

DATA STORE and MIN/MAX: Stores up to 512 readings and identifies minimum and maximum reading.

PROGRAMMABLE READING INTERVAL: 10ms to 999.999s in 1ms increments.

TRIGGER: One-shot or continuous from front panel, IEEE-488 bus, and rear panel BNC.

PROGRAMMABLE TRIGGER DELAY: 1ms to 999.999s in 1ms increments.

DISPLAY: One ten character plus one eight character alphanumeric LED displays with normal/dim/off intensity control.

MAXIMUM VOLTAGE BETWEEN VOLTAGE SOURCE AND CURRENT METER: 500V DC.

MAXIMUM VOLTAGE BETWEEN CHASSIS AND VOLTAGE SOURCE OR CURRENT METER: 500V DC.

REAR PANEL CONNECTORS:
- **Input Connector:** 3-lug triax.
- **Analog Output:** 5-way binding post.
- **External Trigger and Meter Complete:** BNC connectors.
- **IEEE-488 Connector:** Chassis grounded.
- **Voltage Source Output (487 only):** 5-way binding post.
- **Interlock Connector (487 only):** 3-pin miniature DIN.

ENVIRONMENT:
- **Operating:** 0°–50°C, <70% RH up to 35°C; linearly derate 3% RH/°C, up to 50°C.
- **Storage:** –25° to 60°C.

WARM-UP: 2 hours to rated accuracy.

POWER: 105–125V AC or 210–250V AC (external switch selectable), 90–110V and 180–220V AC version available. 50Hz or 60Hz, 45VA maximum.

DIMENSIONS, WEIGHT: 90mm high × 213mm wide × 397mm deep (3½ in. × 8⅜ in. × 15⅝ in.). Net weight 4.25kg (9.3 lbs.).

AMMETER

RANGE	RESOLUTION	ACCURACY (1 Year)* ±(%rdg+offset)	[illegible]	[illegible]
2 nA	10 fA	0.3 + 500 fA	12 ms	70 ms
20 nA	100 fA	0.2 + 3 pA	4 ms	17 ms
200 nA	1 pA	0.15 + 20 pA	800 µs	4 ms
2 µA	10 pA	0.15 + 200 pA	380 µs	2 ms
20 µA	100 pA	0.1 + 2 nA	160 µs	370 µs
200 µA	1 nA	0.1 + 20 nA	160 µs	370 µs
2 mA	10 nA	0.1 + 200 nA	160 µs	370 µs

* When properly zeroed.

MAXIMUM OVERLOAD: 350V peak on nA ranges and 2µA range; 50V peak on 20µA, 200µA, and 2mA ranges. Higher voltage sources must be current limited at 3mA.

INPUT VOLTAGE BURDEN: <200µV (18°–28°C) for inputs <100µA; <2mV for inputs ≥ 100µA; 20µV/°C temperature coefficient.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.15 × applicable accuracy specification)/°C.

NMRR: >60dB at 50Hz (LINE 50Hz integration) or 60Hz (LINE 60Hz integration).

ANALOG OUTPUT:
- **Range:** ±2V for full range input (non-inverting).
- **Accuracy:** ±(2.5% + 3mV); resistive loads >2kΩ; 18°–28°C.
- **Impedance:** <100Ω, DC–2kHz.

RANGING: Automatic or manual.

AUTORANGING TIME: <200ms to final range (analog filter OFF).

MAXIMUM READING RATES (readings/second):

INTEGRATION SETTING	RESOLUTION	EXTERNAL CONTINUOUS INTO DATA STORE	TRIGGERED TRIGGER INTO DATA STORE	[illegible]
FAST	4½-Digit	100	180	16
LINE 60Hz	5½-Digit	40	44	14
LINE 50Hz	5½-Digit	33	38	12

** One-shot on TALK, G7 data format.

VOLTAGE SOURCE (487 only):

RANGE (maximum value)	STEP SIZE (typical)	ACCURACY (1 Year) 18°–28°C ±(%setting+offset)	[illegible]	TEMPERATURE COEFFICIENT [illegible]
±505.00 V	10 mV	0.15 + 40 mV	<1.5 mV	80 ppm+ 2 mV/°C
±50.500 V	1 mV	0.1 + 4 mV	<150 µV	50 ppm+200µV/°C

*** With LO terminal connected to chassis.

SELECTABLE CURRENT LIMIT: 2.5mA ±0.5mA or 25µA ±5µA.

WIDEBAND NOISE: <30mV p-p 0.1Hz to 20MHz.

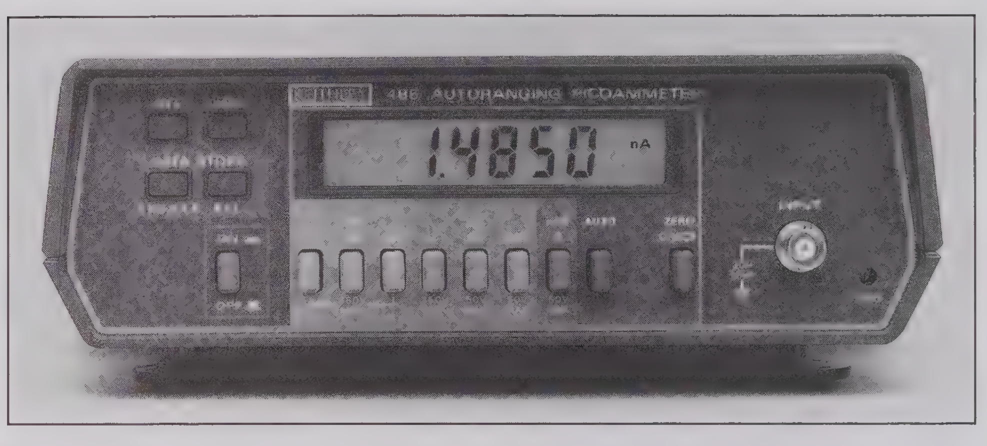
TIME STABILITY: ±(0.003% + 1mV) over 24 hours at constant temperature.

OUTPUT RESISTANCE: <2.5Ω.

485,480 Picoammeters

- 100fA sensitivity
- 200μV maximum voltage burden
- Analog output
- Log I readings
- Optional IEEE-488 interface

IEEE-488



[illegible]

485
Autoranging Picoammeter

485/1758
Autoranging Picoammeter with Rechargeable Battery Pack

485/4853
Autoranging Picoammeter with IEEE-488 Interface

480
Picoammeter

480/1788
Picoammeter with Rechargeable Battery Pack

480/1793
Picoammeter with IEEE-488 Output

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

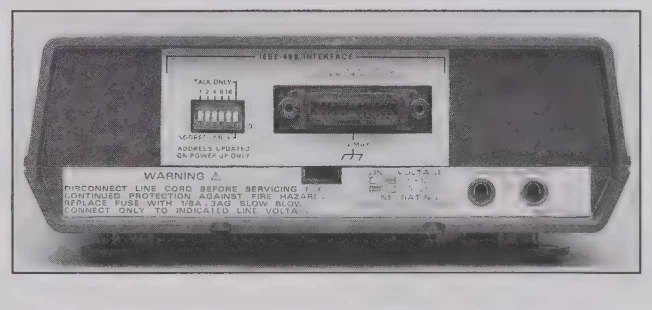
OUTPUT OPTIONS	
1792	Isolated BCD Output (480)
1793	Isolated IEEE-488 Output (480)
4853	IEEE-488 Interface (485)
CABLES	
4801	Low Noise BNC Input Cable, 1.2m (4 ft.)
4802-10	Low Noise BNC Input Cable, 3m (10 ft.), unterminated
4803	Low Noise Cable Kit
ADAPTER	
4804	Male BNC to Female Triax Adapter
RACK MOUNT KITS	
1010	Single Rack Mount Kit
1017	Dual Rack Mount Kit
POWER	
1758	Rechargeable Battery Pack (485)
1788	Rechargeable Battery Pack (480)

See page 163 for descriptions of all accessories.

The Model 485 Autoranging Picoammeter provides 100fA sensitivity with 4½-digit resolution in a low-cost, highly sensitive, easy-to-use instrument. The 485 measures DC current on seven ranges covering 10 decades from 100fA to 2nA. The input can withstand overloads as high as 100V (with 100kΩ limiting resistor) for flexibility in a wide range of applications in test, research, and student labs. An analog output linearly converts the incoming current to voltage for hard copy output or control loop applications.

In addition to 100fA sensitivity, the 485 has both excellent accuracy and low voltage burden. One-year accuracy on the most sensitive range is an impressive 0.4%. The 485's input voltage drop (burden) is actively constrained by feedback techniques to less than 200μV. Thus the 485 makes high accuracy current measurements even in circuits with very low source voltages.

The 485 has several features that facilitate measuring low current. In the AUTORANGE mode, the 485 maximizes resolution. The REL button makes readings relative to the baseline (the reading prior to touching the button). The LOG button converts the display to the logarithm (base 10) of the absolute value of the measured current. Digital calibration is performed from the front panel or over the bus.

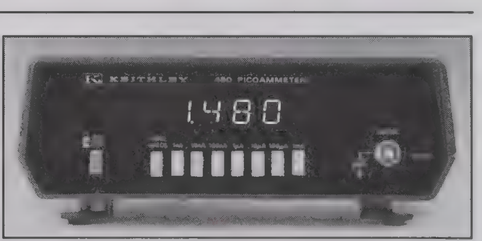

IEEE-488 INTERFACE
TALK ONLY
ADDRESS UPDATED ON POWER UP ONLY
WARNING ⚠
DISCONNECT LINE CORD BEFORE SERVICING
CONTINUED PROTECTION AGAINST FIRE HAZARD
REPLACE FUSE WITH 1/8A, 3AG SLOW BLOW
CONNECT ONLY TO INDICATED LINE VOLTAGE

A 100-point DATA STORE buffer collects and stores measurements at one of 6 automatic reading rates from 3 per second to 1 per hour, or manually with the store button. Minimum and maximum readings are continuously updated at 3 per second in the DATA STORE mode.

Addition of the Model 4853 IEEE-488 Interface to the 485 adds fully programmable computer control. For isolation from the power line or for portability, the 485 can be battery powered with the Model 1758 Rechargeable Battery Pack.

MODEL 480

- **LED display**
- **1pA resolution**
- **Analog output**
- **Optional IEEE-488 output**



The Model 480 is an easy-to-use, sensitive ammeter that resolves 1pA at a low price. Simple controls, LED display, shielded BNC input, high normal mode rejection, and excellent overload specifications make it easy to use. The 480 measures DC current from 1pA per digit (2nA full range) to 2mA, with 3½-digit precision. Seven ranges cover the full span of low-current measurements. The input is simply connected to the circuit under test, the appropriate range selected, and the current read from the LED display.

MODEL 485 RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg + counts)*	ANALOG RISE TIME (10%–90%)	NORMAL MODE REJECTION RATIO (50 or 60Hz)	MAXIMUM CONTINUOUS INPUT**
2 nA	100 fA	0.4 + 4	60 ms	70 dB	350 V DC
20 nA	1 pA	0.4 + 1	60 ms	70 dB	350 V DC
200 nA	10 pA	0.2 + 1	6 ms	65 dB	350 V DC
2 µA	100 pA	0.15 + 1	3 ms	65 dB	350 V DC
20 µA	1 nA	0.1 + 1	3 ms	65 dB	50 V DC
200 µA	10 nA	0.1 + 1	1 ms	65 dB	50 V DC
2 mA	100 nA	0.1 + 1	1 ms	55 dB	50 V DC

*When properly zeroed. **With no limiting resistance: 1000V DC with external 100kΩ series resistance.

MODEL 480 RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg + counts)*	ANALOG RISE TIME (10%–90%)	NORMAL MODE REJECTION RATIO (50 or 60Hz)	MAXIMUM CONTINUOUS INPUT**
2 nA	1 pA	0.8 + 4	70 ms	70 dB	600 V DC
20 nA	10 pA	0.8 + 3	70 ms	70 dB	600 V DC
200 nA	100 pA	0.5 + 3	7 ms	60 dB	600 V DC
2 µA	1 nA	0.5 + 3	7 ms	60 dB	600 V DC
20 µA	10 nA	0.5 + 3	4 ms	50 dB	75 V DC
200 µA	100 nA	0.5 + 3	1 ms	50 dB	75 V DC
2 mA	1 µA	0.5 + 3	1 ms	50 dB	20 V DC

*Up to 70% R.H.

INPUT VOLTAGE BURDEN: <200µV.

RANGING: 480: Manual. **485:** Manual or autoranging.

AUTORANGING TIME (485): Average 250ms per range change.

SETTLING TIME AT DISPLAY: <1 second to within 2 counts on fixed range.

CONVERSION PERIOD: 485: 300ms. **480:** 400ms.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, DC to 60Hz sine wave.

ANALOG OUTPUT (485): Output Voltage: +1V = –10000 counts, except +100mV = –10000 counts on 2nA range. **Output Resistance:** 1kΩ.

ANALOG OUTPUT (480): Output Voltage: 1V = 1000 counts. **Output Resistance:** 1kΩ.

REL (485): Pushbutton allows zeroing of on-range readings. Allows relative readings to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATA STORE and MIN/MAX (485): 100 reading storage capacity; records data at one of six selectable rates from 3 readings/second to 1 reading/hour, or by manual triggering. Also detects and stores maximum and minimum readings continuously while in the DATA STORE mode.

LOG (485): Displays logarithm (base 10) of the absolute value of the measured current (examples: –3.000 = ±1mA; –6.301 = ±0.5µA).

IEEE BUS IMPLEMENTATION (485 Option 4853)

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL2, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Zero Check, REL, LOG, Trigger, Calibration, EOI, SRQ, Status, Output Format, Terminator.

GENERAL

DISPLAY: 485: 4½-digit LCD, 0.5 in. height; polarity, range, and status indication. **480:** Four 0.5 in. LED digits with appropriate decimal point and polarity indication.

OVERRANGE INDICATION: 485: "OL" displayed. 480: Display blinks all zeros above 1999 counts.

CONNECTORS: Input: BNC. **Analog Output:** Banana jacks.

OPERATING ENVIRONMENT: 0°–50°C, <70% RH up to 35°C; linearly derate 3% RH/°C up to 50°C.

STORAGE ENVIRONMENT: –25° to 60°C.

POWER: 105–125V or 210–250V (switch selected), 90–110V available, 50–60Hz, 12VA (20VA on 480).

DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (4 lbs.).

VOLTAGE BURDEN CAN CAUSE ERRORS AT ANY CURRENT LEVEL

The voltage burden is the terminal voltage of an ammeter. An ideal ammeter will not alter the current flowing in a circuit when connected in place of a conductor. Thus, it must have zero resistance and therefore zero voltage burden.

Digital multimeters use the shunt ammeter technique shown in **Figure 1** to measure current. The measurement method is to develop a voltage across a sensing resistor. The resistor is chosen such that 200mV corresponds to the maximum current reading on a selected range. The voltage burden specification is the 200mV developed across the sensing resistor.

Feedback picoammeters such as the 480/485 and Keithley electrometers use a technique in which the voltage burden is the input voltage of an op amp, as shown in **Figure 2**.

The output voltage of the op amp is precisely related to the input current. Since input voltage is output voltage divided by op amp gain (typically 100,000), the voltage burden is only microvolts. Maximum specified voltage burden of the 480/485 is only 0.2mV.

An example of the problems caused by high voltage burden is shown in **Figure 3**. In measuring the emitter current of a transistor, the DMM causes a very significant error (200mV out of 300mV) while the 480/485 voltage burden creates negligible error (0.2mV out of 300mV). Even though the basic measurement is well within the range of a DMM, the 480/485 makes a more accurate measurement since, due to its low voltage burden, the 480/485 is much closer to an ideal ammeter.

FIGURE 1

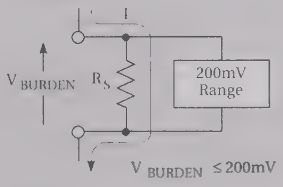


FIGURE 2

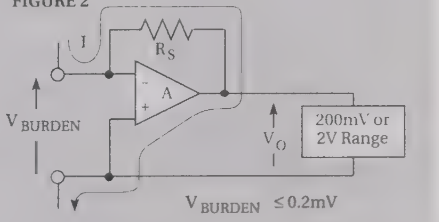
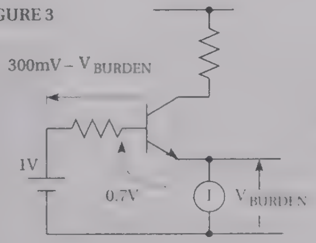


FIGURE 3



Ideal Ammeter: $V_{BURDEN} = 0$
$= 0\%$ error

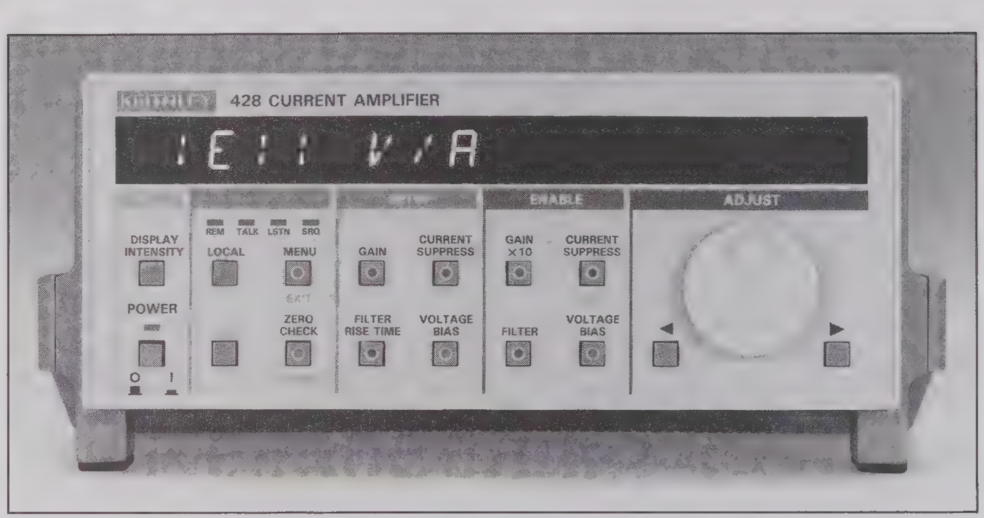
480/485: $V_{BURDEN} \leq 0.2$mV
$\leq 0.07\%$ error

DMM: $V_{BURDEN} \leq 200$mV
$\leq 67\%$ error

428 Current Amplifier

- 2µs rise time
- 1.2fA rms noise
- Up to 10^{11} V/A gain
- IEEE-488 interface available

IEEE-488



ORDERING INFORMATION

428-MAN
Manual Current Amplifier

428-PROG
Programmable Current Amplifier with IEEE-488 Interface

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

CABLES	
4801	Low Noise BNC Input Cable, 1.2m (4 ft.)
ADAPTERS	
4804	Male BNC to 2-Lug Female Triax Adapter
6147	2-Slot Male Triax to Female BNC Adapter
7078-TRX-BNC	3-Slot Male Triax to Female BNC Adapter
RACK MOUNTS	
4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit

See page 163 for descriptions of all accessories.

The new Model 428 Current Amplifier converts fast, small currents to a voltage, which can be easily digitized or displayed by an oscilloscope, waveform analyzer, or data acquisition system. It uses a sophisticated "feedback current" circuit to achieve both fast rise times and sub-picoamp noise. The gain of the 428 is adjustable in decade increments from 10^3V/A to 10^{11}V/A, with selectable rise times from 2µs to 300ms.

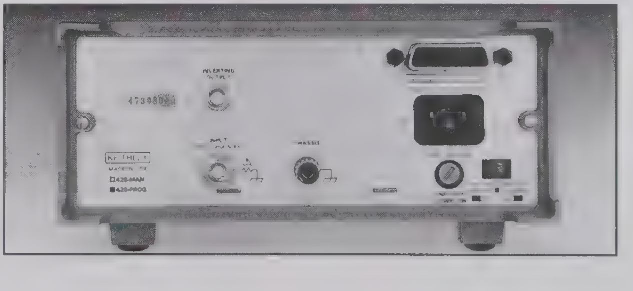
The 428 incorporates a second-order Bessel-function filter that minimizes noise without increasing rise time on high-gain ranges. This may be defeated in situations where 6dB/octave roll-off is desired, as in control loops of scanning tunnel electron microscopes.

Input and output connections to the 428 are made with BNC connectors. INPUT HI is connected to a programmable ±5V supply, which permits suitable bias voltages to be applied to devices-under-test, or current collectors. This eliminates the need for a separate bias supply.

For applications where voltage offset errors exist, the ZERO CHECK and OFFSET functions can be used, thereby maintaining maximum instrument accuracy. Current suppression is also available up to 5mA, useful for suppressing background currents, such as dark currents.

The 428 also incorporates a new exterior design with simplified front panel operation, improved display, and convenient system integration. New pushbutton controls have an LED in the center to easily tell if that function is activated. The display features three selectable intensities (bright, dim, and off) for use in light-sensitive environments. All set-up values can be displayed from the front panel.

The Model 428-MAN is a manual version with no IEEE-488 interface capabilities. The Model 428-PROG includes the IEEE-488 interface.



Applications

The 428 satisfies a broad range of applications in research and device labs due to its cost-effective ability to amplify fast, low currents. A few of these applications include:

Surface Science Studies:

- Scanning Tunneling Electron Microscope system amplifier.
- Observation of secondary electron emission, as in X-ray and beam line currents.

Laser and Light Measurements:

- Fast, sensitive amplifier for use with PMTs and photodiodes.
- Analysis of fast photoconductive materials.
- IR detector amplifier.

Transient Phenomena:

- Current DLTS studies.
- Breakdown in devices and dielectric materials.

The 428 as Preamplifier to an Oscilloscope

In this widespread application, the 428 is connected to an oscilloscope or waveform digitizer and very low currents are amplified, converted to a voltage, and sent into the scope to be displayed in real time.

Current Amplifier 428

	ACCURACY¹		LOW NOISE²		MAXIMUM SPEED⁴		
GAIN SETTING V/A	±(%input + offset)	TEMPERATURE COEFFICIENT ±(%input + offset)/°C	RISE TIME³ (10%–90%) ms	NOISE RMS	RISE TIME³ (10%–90%) µs	NOISE RMS	DC INPUT RESISTANCE
10^3	0.45+ 1.2 µA	0.01 + 40 nA	0.1	90 nA	2	100 nA	< 0.6 Ω
10^4	0.31+ 120 nA	0.01 + 4 nA	0.1	9 nA	2	15 nA	< 0.7 Ω
10^5	0.31+ 12 nA	0.01 + 400 pA	0.1	900 pA	5	2 nA	< 1.6 Ω
10^6	0.34+ 1.2 nA	0.01 + 40 pA	0.1	90 pA	10	500 pA	< 10 Ω
10^7	0.5+ 122 pA	0.015 + 4.3 pA	0.1	9 pA	15	200 pA	<100 Ω
10^8	1.4+ 14 pA	0.015 + 700 fA	1	0.5 pA	40	30 pA	< 1 kΩ
10^9	2.5+ 3 pA	0.025 + 300 fA	10	50 fA	100	10 pA	< 10 kΩ
10^{10}	2.5+ 1.6 pA	0.025 + 250 fA	100	4 fA	250	2 pA	<100 kΩ
10^{11}*	2.7+ 1.6 pA	0.028 + 250 fA	300	1.2 fA	250	2 pA	<100 kΩ

[1] When properly zeroed using zero correct.
[2] Selectable filtering will improve noise specifications; see operator's manual for details (typical value shown).
[3] Bandwidth = 0.35/rise time.
[4] With up to 100pF shunt capacitance; autofilter on; low pass filter off.
* 10^{11} setting is 10^{10} setting with GAIN ×10 enabled; other entries are for GAIN ×10 disabled.

SPECIFICATIONS

INPUT:

Voltage Burden: <200µV (18°–28°C) for inputs <100µA; <10mV for inputs ≥ 100µA; 20µV/°C temperature coefficient.

Maximum Overload: 100V on 10^4 to 10^{11}V/A ranges; 10V on 10^3V/A range. Higher voltage sources must be current limited at 10mA.

OUTPUT:

Range: ±10V, 1mA; bias voltage off.
Impedance: <100Ω DC–175kHz.

LOW PASS FILTER:

Ranges: 10µs to 300ms (±25%) in 1, 3, 10 sequence or OFF.
Attenuation: 12dB/octave.

GAIN ×10: Rise time, noise, and input resistance are unchanged when selecting GAIN ×10; gain accuracy and temperature coefficient are degraded by 0.2% and 0.003%/°C respectively.

CURRENT SUPPRESSION

Range	Resolution	Accuracy ±(%setting + offset)
±5 nA	1 pA	3.0 + 10 pA
±50 nA	10 pA	1.6 + 100 pA
±500 nA	100 pA	0.8 + 1 nA
±5 µA	1 nA	0.7 + 10 nA
±50 µA	10 nA	0.6 + 100 nA
±500 µA	100 nA	0.6 + 1 µA
±5 mA	1 µA	0.6 + 10 µA

BIAS VOLTAGE:

Range: ±5V.
Resolution: 2.5mV.
Accuracy: ±(1.1%rdg + 25mV).

IEEE-488 BUS IMPLEMENTATION (428-PROG)

MULTILINE COMMANDS: DCL, LLO, SDC, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, L4, LE0, SR1, RL1, PP0, DC1, DT0, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters and controls programmable except for IEEE-488 bus address.

EXECUTION SPEED: (measured from DAV true to RFD true on bus)

Zero correct & autosuppression commands:	<3 s
Save/Recall Configuration commands:	<500 ms
All other commands:	<40 ms

GENERAL

DISPLAY: Ten character alphanumeric LED display with normal/dim/off intensity control.

REAR PANEL CONNECTORS:
Input BNC: Common connected to chassis through 1kΩ.
Output BNC: Common connected to chassis.
IEEE-488 Connector: 428-PROG only.
5-Way Binding Post: Connected to chassis.

EMI/RFI: Complies with the RF interference limits of FCC Part 15 Class B and VDE 0871 Class B.

WARM-UP: 1 hour to rated accuracy.

ENVIRONMENT: Operating: 0°–50°C, <70% R.H. up to 35°C; linearly derate R.H. 3%/°C up to 50°C. **Storage:** –25°C to 65°C.

POWER: 105–125 VAC or 210–250 VAC, switch selected. (90–110/180–220 VAC available.) 50Hz or 60Hz. 45VA maximum.

DIMENSIONS, WEIGHT: 90mm high × 213mm wide × 397mm deep (3½ in. × 8⅜ in. × 15⅝ in.). Net weight 3.4kg (7.4 lbs.).

Technical Data

Significant errors may be introduced in low voltage measurements by noise and drift sources which can be ignored at higher levels. These sources include thermal EMFs, magnetic fields, ground loops, and Johnson noise. Taking steps to understand and minimize these factors is crucial for making meaningful measurements at low voltage.

Thermal EMFs

Thermoelectric voltages are the most common source of errors in low-voltage measurements. These voltages arise when junctions of dissimilar materials are at different temperatures, as in **Figure 1**. Values for the thermoelectric power (Q_{AB}) of various materials with respect to copper are shown in **Table 1**.

TABLE 1: Thermoelectric Potentials

Materials	Thermoelectric Potential
Cu - Cu	≤0.2 µV/°C
Cu - Ag	0.3 µV/°C
Cu - Au	0.3 µV/°C
Cu - Cd/Sn Solder	0.3 µV/°C
Cu - Pb/Sn Solder	1.3 µV/°C
Cu - Kovar	40 µV/°C
Cu - Si	400 µV/°C
Cu - Cu Oxide	1400 µV/°C

Constructing circuits using the same material for conductors minimizes the thermal EMF. For example, gold or silver has a lower thermal EMF than lead-tin solder by a factor of ten. And connections made by crimping copper sleeves and lugs result in cold-welded copper-to-copper junctions which generate even less thermal EMF.

Minimizing temperature gradients within the circuit also reduces thermal EMF. A technique for accomplishing this is to place all junctions in close proximity and provide good thermal coupling to a common massive heat sink. This coupling must take place through electrical insulators having high thermal conductivity. Since most electrical insulators do not conduct heat well, special insulators such as hard anodized aluminum, beryllium oxide, specially filled epoxy resins, sapphire, or diamond must be used to thermally couple junctions to the heat sink.

In addition, allowing test equipment to warm up and reach thermal equilibrium in a constant ambient temperature also minimizes thermal EMF effects. Any remaining thermal EMF which is relatively constant can be compensated by zero controls provided on the measuring instrument. To keep ambient temperatures constant, equipment should be kept away from direct sunlight, exhaust fans, and similar sources of hot or cold air. Wrapping connections in insulating foam (e.g., polyurethane) also minimizes ambient temperature fluctuation due to air movement.

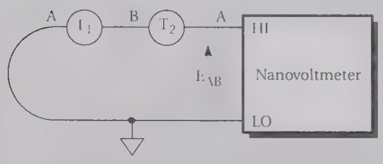
Magnetic Fields

The motion of circuit leads in magnetic fields generates spurious voltages. Even the earth's relatively weak magnetic field can generate nanovolts in dangling leads, so leads must be kept short and rigidly tied down.

Basic physics shows that the amount of voltage a magnetic field induces in a circuit is proportional to the area the circuit leads enclose, as shown in **Figure 2**. Thus, leads must be run close together and/or magnetically shielded to minimize induced magnetic voltages. One commonly-used magnetic shielding material is mu-metal, a special alloy with high permeability at low magnetic densities. **Figure 3** shows two ways of locating the leads from the source to the voltmeter: In **Figure 3a**, a large area is enclosed (thus a large voltage is developed); in **Figure 3b**, much less area is enclosed, thus minimum voltage is developed.

Conductors which carry large currents should also be shielded or run as twisted pairs to

FIGURE 1: Thermal EMFs



The thermal EMF developed by dissimilar metals A and B in a series circuit is:

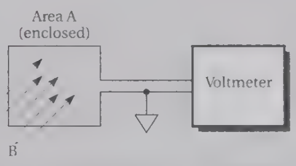
$$E_{AB} = Q_{AB}\,(T_1 - T_2)$$

Temperature of the A to B junction in °C

Temperature of the B to A junction in °C

Thermoelectric voltage coefficient of material A with respect to B, µV/°C

FIGURE 2: Low Voltages Generated by Magnetic Fields



The voltage developed due to a field passing through a circuit enclosing a prescribed area is:

$$E_B = \int_A \frac{\partial \vec{B}}{\partial t}\, dA$$

$\vec{B}$ = Magnetic field intensity

$\frac{\partial \vec{B}}{\partial t}$ = Rate of change of $\vec{B}$ with time

Integral is to be evaluated over the area enclosed by the circuit

FIGURE 3: Minimizing Interference from Magnetic Loops

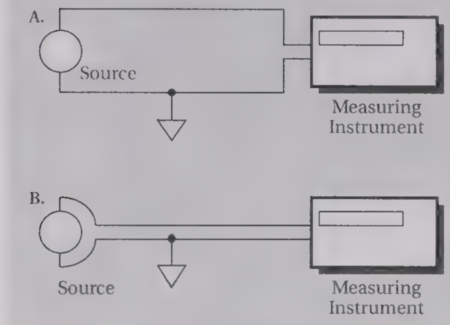
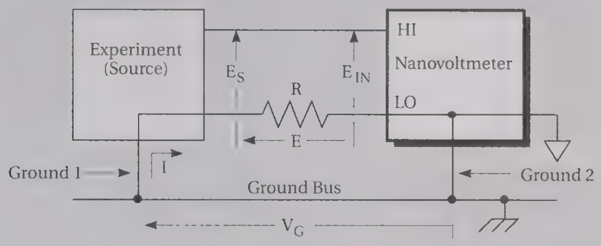


FIGURE 4: Unwanted Voltages Generated by Ground Loops

FIGURE 4A: Multiple Grounds (Ground Loops)



Input voltage to the nanovoltmeter is:

$E_{IN} = E_S + I R$

Resistance of input LO connection (typically around 100mΩ)

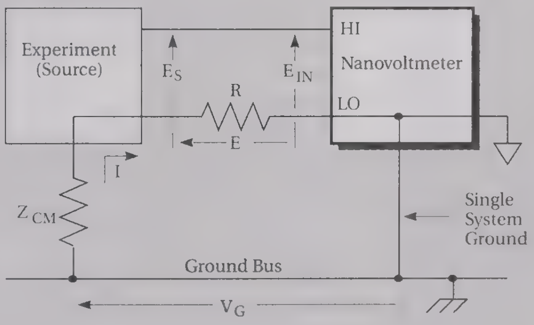
Current passing through input LO connection due to ground voltages (V_G) in the ground bus (magnitude may be amperes)

Source voltage (desired signal)

I R may exceed E_S by orders of magnitude.

$E_{IN} \approx I R$

FIGURE 4B: Single System Ground



Input voltage to the nanovoltmeter is:

$E_{IN} = E_S + I R$

Resistance of input LO connection (typically around 100mΩ)

Current passing through Z_{CM} (MΩ or GΩ) connection due to V_G and currents in the source (magnitude is typically nA's)

Source voltage (desired signal)

$E_{IN} \approx E_S$, since I R is now insignificant compared to E_S.

prevent generating magnetic fields that affect other circuits.

In addition to these techniques, AC signals from magnetic fields can be filtered at the input of the instrument, and the instrument can be physically moved further from the source of a (high) magnetic field.

Ground Loops

Noise and error voltages also arise from so-called ground loops. When the source and the measuring instrument are both connected to a common ground bus, a loop is formed as shown in **Figure 4a**. A voltage V_G between the source and instrument grounds will cause a current (I) to flow around the loop. This current will create an unwanted voltage in series with the source voltage. From Ohm's Law:

$E = IR$

where E = ground loop interfering voltage; R = the resistance in the signal path through which the ground loop current flows; and I = the ground loop current.

A typical example is a number of instruments plugged into power strips on different instrument racks. Frequently, there is a small difference in potential among the ground points. This potential difference can cause large currents to circulate and create unexpected voltage drops.

The cure for ground loops is to ground all equipment at one point. The easiest way of accomplishing this is to use isolated power sources and instruments, then find a single good earth-ground point for the entire system, as shown in **Figure 4b**.

Johnson Noise

The fundamental limit to measurement is Johnson noise in the source resistance. In any resistance, thermal energy produces motion of charged particles. This charge movement results in noise which is often called Johnson or thermal noise. The power available from this motion is given by:

$P = 4kT\Delta f$

where k = Boltzmann's Constant (1.38×10^{-23}J/°K), T = temperature in °K, and Δf = noise bandwidth in Hz. Johnson voltage noise developed in a resistor R is:

$E = \sqrt{4kTR\Delta f}$ volts, rms

At room temperature (300°K), the above equation becomes:

$E_{p\text{-}p} = 6.5 \times 10^{-10} \sqrt{R\Delta f}$

Sensitive Digital Voltmeter

- 1nV sensitivity
- 5ppm transfer stability
- High input resistance: >10GΩ
- 100 readings per second
- 6½-digit resolution
- 3nV rms noise

IEEE-488

[illegible]

182/1506
Sensitive Digital Voltmeter with line cord, instruction manual, Quick Reference Guide and 1506 Low Thermal Input Cable, 1.2m (4 ft.), clips

182/1507
Sensitive Digital Voltmeter with line cord, instruction manual, Quick Reference Guide and 1507 Low Thermal Input Cable, 1.2m (4 ft.), lugs

182/1482
Sensitive Digital Voltmeter with line cord, instruction manual, Quick Reference Guide and 1482 Low Thermal Input Cable, 3m (10 ft.), unterminated

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CONNECTORS, ADAPTERS

1483	Low Thermal Connection Kit
1484	Refill Kit for 1483 Kit
1485	Female Low Thermal Input Connector
1486	Male Low Thermal Input Connector
1488	Low Thermal Shorting Plug

CABLES

1481	Low Thermal Input Cable, 1.2m (4 ft.), clips
1482	Low Thermal Input Cable, 3m (10 ft.), unterminated
1506	Low Thermal Input Cable, 1.2m (4 ft.), clips
1507	Low Thermal Input Cable, 1.2m (4 ft.), lugs

TEST FIXTURE

8003	Low Resistance Test Fixture

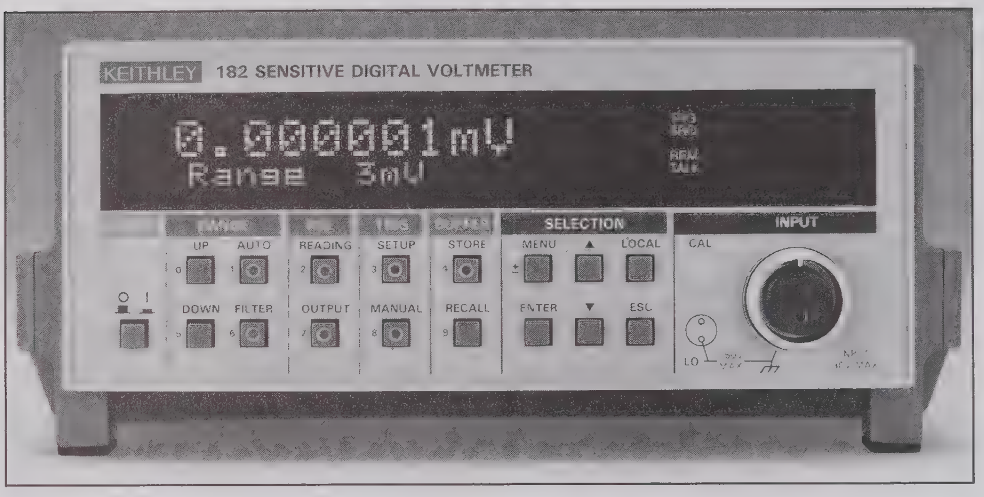
CALIBRATION

262	Low Thermal Voltage Divider

RACK MOUNTS

4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit

See page 163 for descriptions of all accessories.



The new Keithley Model 182 Sensitive Digital Voltmeter (SDV) provides unmatched accuracy and sensitivity for measuring low voltages.

1nV sensitivity, freedom from lead reversal errors, and the industry's best noise rejection are just a few of the key advantages that can improve the accuracy of your test procedure.

The Model 182 SDV offers the highest accuracy available for making low voltage measurements. This programmable unit holds noise to just 3nV rms on its 3mV range, providing highly stable readings for low voltage applications.

The Model 182 operates at least 50 times faster than other low voltage measuring instruments, while maintaining better accuracy. It requires just 60ms to take a measurement with 1nV sensitivity. Reading rates up to 100 readings per second are also possible with microvolt sensitivity.

The 182 offers high input resistance, greater than 10GΩ on all voltage ranges, which also helps ensure accuracy by minimizing loading effects. This allows direct measurement of standard cells. The 182 will monitor chemical-based standard cells, 10V solid state voltage references, and even Josephson junction standards.

The Model 182 was specifically designed for accurate measurements in low voltage applications such as: standard cell intercomparisons, calibration, superconductivity experiments, Josephson junction work, microcalorimetry, crack fatigue testing of metals, offset voltage measurements of op-amps, analog switches and other components, and contact resistance testing of connectors, relays and switches.

Low Noise

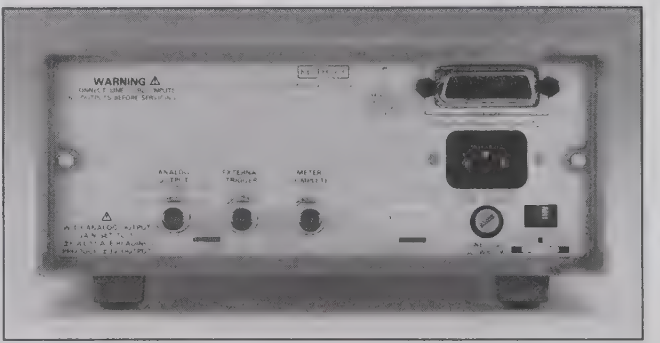
For many measurements the greatest limiting factor is noise. The 182 achieves performance very close to the theoretical Johnson noise of the input components.

The 182's low noise, resolution and stability are generally sufficient to obtain satisfactory error reduction with fewer readings required for averaging, which can save considerable test time.

Pump-out, which is RFI noise conducted out of an instrument via the input terminals, is reduced to extremely low levels over a wide frequency range in the 182. This instrument is suitable for use with the most sensitive semiconductor devices, Josephson junctions, and materials.

Other Functions

The Model 182 contains an internal memory that stores 1024 readings, including the time of each reading with respect to the trigger. Up to 1024 readings may be averaged by setting the buffer size. In addition to the average, standard deviation, minimum, and maximum readings can also be recalled. These statistical functions may be performed from the front panel or over the IEEE-488 bus.



Sensitive Digital Voltmeter 182

The Model 182 offers multiple triggering sources, including a rear panel BNC, IEEE-488 bus, and the front panel, providing a wide range of options for setting up test systems. Fast recovery from open inputs makes it easy to use with switching matrices. A trigger delay feature allows users to program in a delay between the trigger and the reading to allow for settling time. The continuous or one-shot trigger collects data one point at a time, or in multiple readings.

A choice of three digital filters and one analog filter provide optimum measurement capabilities for any electrically noisy environment. Unwanted signals are attenuated to produce negligible influence on the measurement.

Multiple Measurement Capabilities

Many low voltage applications require that measurements be made at multiple test points. A signal scanner may be used in direct connection with the 182 SDV to measure different components, compare multiple voltage references, or determine the voltage at several different locations on a material.

ANALOG OUTPUT

MAXIMUM OUTPUT: ±3V.

ACCURACY: ±(0.15% of output + 1mV).

OUTPUT RESISTANCE: 1kΩ nominal.

GAIN: Adjustable from 10^{-3} to 10^{6}. With gain set to 1, a full range input will produce a 3V output.

OUTPUT REL: Selects value of input which represents 0V at output. The reference value can be either a programmed value or the value of the previous input.

DATA BUFFER

BUFFER TYPE: Linear or circular. Each location stores the reading and the time since the first trigger.

BUFFER MEMORY LENGTH: Programmable 1 to 1024 locations.

BUFFER STATISTICS: Number of Readings, Location, Value, Timestamp, Maximum Reading, Minimum Reading, Average and Standard Deviation.

TRIGGER

MODES: ONE SHOT or MULTIPLE readings per trigger.

INTERVAL: In MULTIPLE Mode, the time between readings can be programmed from 10ms to 999.999s in 1ms increments.

DELAY: Time between trigger and start of first measurement. Selectable from 0 to 999.999s in 1ms increments.

SOURCES: Rear panel BNC (external), front panel button (manual), IEEE-488 (GET, "X", or Talk).

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters programmable except for IEEE-488 bus address.

VOLTMETER

[illegible]

RANGE	RESOLUTION	[illegible]	[illegible]	[illegible]	[illegible]
3 mV	1 nV	20 + 16*	40 + 16*	60 + 16*	5 + 9*
30 mV	10 nV	20 + 6*	40 + 6*	60 + 6*	3 + 2*
300 mV	100 nV	15 + 6	35 + 6	55 + 6	3 + 2
3 V	1 µV	10 + 4	30 + 6	50 + 6	3 + 2
30 V	10 µV	10 + 4	30 + 6	50 + 6	3 + 2

* When properly zeroed using REL function.

[1] Integration set to 1 Power Line Cycle (PLC), Analog Filter off, Digital Filter set to Medium, 1 hour warm-up. Accuracy specifications exclude calibrator accuracy. Add 4 ppm of reading to accuracy specifications for factory calibration.

ACCURACY TEMPERATURE COEFFICIENT: ± (4 ppm of input + 1 ppm of range)/°C, 0°–18°C and 28°–35°C.

MAXIMUM INPUT: 120V for 10 seconds, 35V continuous.

NOISE vs. SOURCE RESISTANCE[1]**:**

SOURCE RESISTANCE	NOISE	ANALOG FILTER	DIGITAL FILTER
0 - 100 Ω	15 nV p-p	off	medium
1 kΩ	20 nV p-p	off	medium
10 kΩ	50 nV p-p	off	medium
100 kΩ	160 nV p-p	on	slow
1 MΩ	500 nV p-p	on	slow

[1] 3mV range, Integration set to 1 PLC, 2 minute observation, ±1°C.

INPUT IMPEDANCE: >10GΩ at 6½ digits, >1GΩ at 4½ digits, 5nF nominal.

INPUT BIAS CURRENT: <50pA.

COMMON MODE CURRENT: <50nA p-p at 50Hz or 60Hz.

EFFECTIVE COMMON MODE REJECTION RATIO[1]**:**

[illegible]	[illegible]
3 mV - 3 V	160 dB
30 V	140 dB

[1] At DC, 50Hz or 60Hz (± 0.05%) with 1kΩ in either input lead.

NORMAL MODE REJECTION RATIO[1]**:**

[illegible]	[illegible]
3 mV	90 dB
30 mV - 3 V	80 dB
30 V	60 dB

[1] At 50Hz or 60Hz (±0.05%), Analog Filter On, Digital Filter set to Medium, Integration set to 1 PLC.

ANALOG FILTER: Programmable for Off or On. Nominal 8Hz bandwidth.

DIGITAL FILTER: Programmable for Off, Fast, Medium or Slow response.

INTEGRATION TIMES: 3ms, 1 PLC, or 100ms.

EXAMPLE READING RATES

RANGE	INTEGRATION	RESOLUTION	READINGS PER SECOND
30 V	3 ms	1 mV	100[1]
3 mV	1 PLC	1 nV	15[2]
3 mV	1 PLC	1 nV	17[3]
3 mV	1 PLC	1 nV	4[4]

[1] Into Data Buffer, Analog Filter off, Digital Filter off, Analog Output in source mode.

[2] Into Data Buffer, Multiple Trigger, Analog Filter off, Digital Filter on.

[3] IEEE-488 bus, Trigger on Talk, G0 format, Analog Filter off, Digital Filter off.

[4] IEEE-488 bus, Trigger on Talk, G0 format, Analog Filter on, Digital Filter off.

READING REL: Selects value of input which represents 0V reading. The reference value can be either a programmed value or the value of the previous input.

MAXIMUM READING: 3,029,999 counts.

GENERAL

RANGING: Manual or autoranging. Measurement range is displayed.

CALIBRATION: Closed case. Internal ratiometric calibration of 3mV and 30mV ranges. Calibrator must provide 300mV, 3V, and 30V. Calibration can be done via the front panel or the IEEE-488 bus.

POWER-UP SETTINGS: Can be programmed by the user.

SELF-TEST: Tests Display, RAM, ROM and EEPROM.

DISPLAY: Vacuum fluorescent, two lines, 49 characters plus annunciators.

FRONT PANEL CONNECTOR: Special low thermal shielded connector.

REAR PANEL CONNECTORS: Analog output, External Trigger input, Meter Complete: BNC. IEEE-488 connector and BNC connectors are chassis grounded.

WARM-UP: 1 hour to rated accuracy.

ISOLATION: 350V peak from either input terminal to earth ground. Impedance from either terminal to earth ground is >1GΩ paralleled by <400pF.

SAFETY: Designed to UL-1244.

EMI/RFI: Meets VDE-0871 class B limits.

OPERATING ENVIRONMENT: 0°–35°C, <80% RH.

STORAGE ENVIRONMENT: –25° to 65°C.

POWER: 105–125V AC or 210–250 V AC (rear panel switch selectable). 90–110V AC or 180–220V AC version available. 50Hz or 60Hz, 35VA maximum.

DIMENSIONS, WEIGHT: 90mm high × 213mm wide × 397mm deep (3½ in. × 8⅜ in. × 15⅝ in.). Net weight 3.4kg (7.4 lbs).

181 Nanovoltmeter

- **10nV sensitivity**
- **10nV/°C stability**
- **Analog output**
- **6½-digit resolution**
- **Fully programmable**
- **Standard IEEE-488 interface**
- **Pushbutton zero**

ORDERING INFORMATION

181
Digital Nanovoltmeter with IEEE-488 Interface and 1506 Low Thermal Input Cable.

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

CONNECTORS, ADAPTERS

1483	Low Thermal Connection Kit
1484	Refill Kit for 1483 Kit
1485	Female Low Thermal Input Connector
1486	Male Low Thermal Input Connector
1488	Low Thermal Shorting Plug

CABLES

1481	Low Thermal Input Cable, 1.2m (4 ft.), Clips
1482	Low Thermal Input Cable, 3m (10 ft.), unterminated
1506	Low Thermal Input Cable (4 ft., clips)
1507	Low Thermal Input Cable (4 ft., plugs)

TEST FIXTURE

8003	Low Resistance Test Fixture

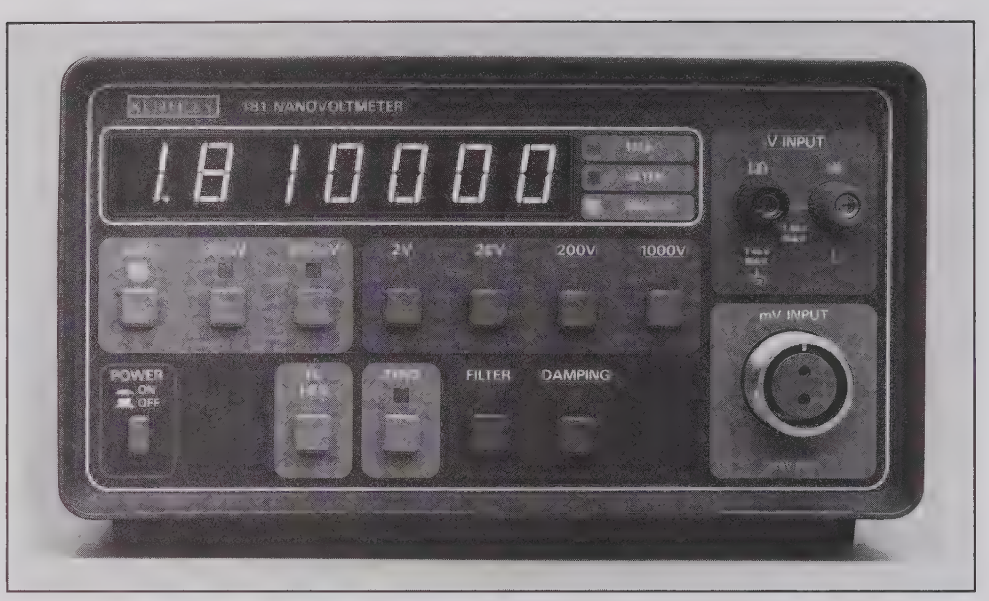
CALIBRATION

262	Low Thermal Voltage Divider (page 72)

RACK MOUNTS

1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

See page 163 for descriptions of all accessories.



DC VOLTS

RANGE	RESOLUTION	ACCURACY (±%rdg+counts) 24 Hr., 23°±1°C	1 Yr., 18°–28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°–18°C & 28°–35°C	INPUT RESISTANCE	MAXIMUM ALLOWABLE INPUT	NMRR AT LINE FREQUENCY
2 mV	10 nV	0.006 + 5 *	0.015 + 5*	0.002 + 3	>1 GΩ	120 V**	>90 dB
20 mV	100 nV	0.006 + 2 *	0.015 + 2*	0.002 + 0.5	>1 GΩ	120 V**	>80 dB
200 mV	1 µV	0.006 + 2	0.015 + 2	0.002 + 0.2	>1 GΩ	120 V**	>80 dB
2 V	10 µV	0.004 + 1.5	0.007 + 2	0.0007 + 0.2	>1 GΩ	1000 V**	>60 dB
20 V	100 µV	0.004 + 1.5	0.01 + 2	0.0008 + 0.2	10 MΩ	1000 V	>60 dB
200 V	1 mV	0.004 + 1.5	0.01 + 2	0.0008 + 0.2	10 MΩ	1000 V	>60 dB
1000 V	10 mV	0.005 + 1.5	0.01 + 2	0.0012 + 0.2	10 MΩ	1000 V	>60 dB

*When properly zeroed. **10 seconds maximum; 35V rms continuous.

CMRR: 160dB on mV ranges, 140dB on V ranges; at DC and line frequency (50 or 60Hz).

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

PROGRAMMABLE PARAMETERS:

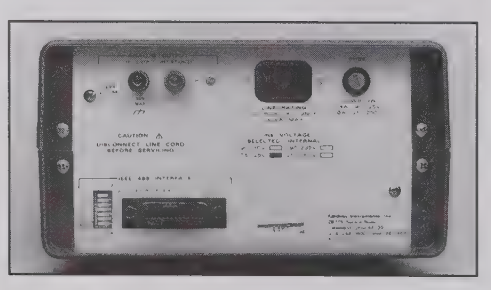
Front Panel Controls: Range, Filter, Zero, Damping, Hi Resolution.

Internal Parameters: SRQ Response, Trigger Modes, Data Terminators.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

TRIGGER MODES: One Shot: Updates output buffer once at first valid conversion after trigger on TALK and/or GET. Continuous: Updates output buffer at all valid conversions after trigger.

IEEE-488



GENERAL

DISPLAY: Seven 0.5 in. LED digits with appropriate decimal point and polarity.

NOISE: <30nV p-p on lowest range with Filter on.

INPUT CAPACITANCE: 5000pF on mV ranges.

SETTLING TIME: 0.5s to within 25 counts of final reading with Filter on, Damping off.

FILTER: 3-pole digital; RC = 0.5, 1, or 2 seconds depending on range.

CONVERSION SPEED: 4 readings/second.

OVERLOAD INDICATION: Display indicates polarity and OFLO.

ANALOG OUTPUT: Accuracy: ±(0.15% of displayed reading + 1mV). **Time Constant:** 400ms. **Level:** ±2V full scale on all ranges; ×1 or ×1000 gain.

ISOLATION: Input LO to Output LO or power line ground: 1400V peak, 5×10^5V•Hz, $>10^9\Omega$ paralleled by 1500pF.

WARM-UP: 1 hour to rated accuracy.

ENVIRONMENTAL LIMITS: Operating: 0°–35°C, 0%–80% relative humidity. **Storage:** –25° to +65°C.

POWER: 105–125V or 210–250V (internal switch selected), 50–60Hz, 30VA maximum.

INPUT CONNECTORS: Special low thermal for 200mV and lower ranges. Binding posts for 2V to 1000V ranges.

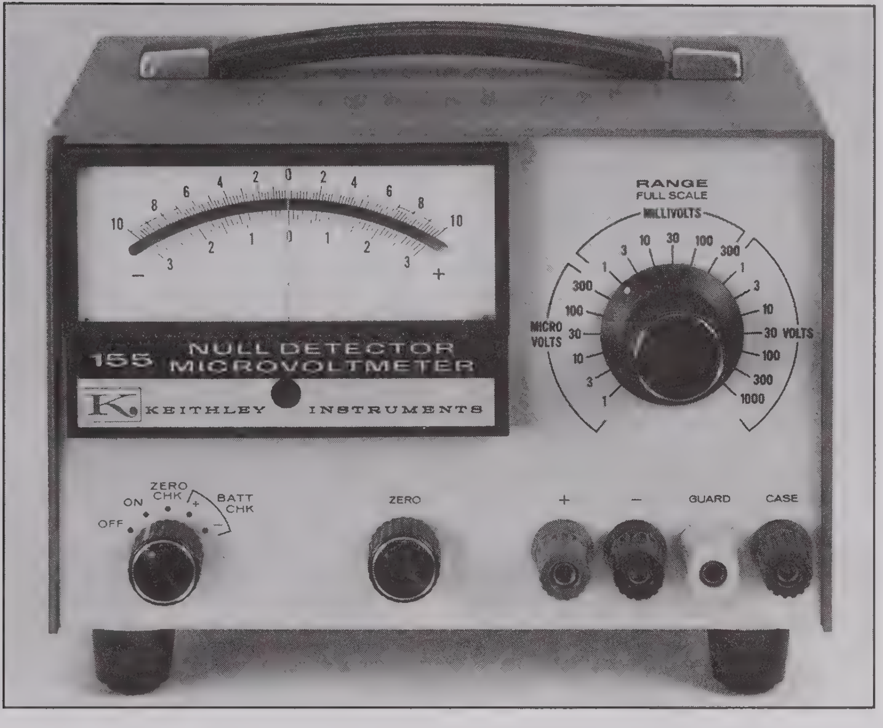
DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.85kg (8.5 lbs.).

ACCESSORY SUPPLIED: Model 1506 Low Thermal Input Cable.

Null Detector/Microvoltmeter

155

- 150nV to 1kV
- 1000-hour battery life
- $10^{12}\Omega$ isolation



The Model 155 Null Detector-Microvoltmeter is a high-performance, low-cost instrument with better than 150nV resolution and full-scale ranges up to 1kV. Its electrical and physical ruggedness, broad range, and high common- and normal-mode rejection make it one of the most versatile voltmeters available for applications in standards labs, development labs, production testing, and basic research.

As a null detector, the guarded battery-operated 155 is often used with potentiometers, bridges, Kelvin-Varley dividers, and for amplifier gain and linearity measurements. The 155 can recover from 100V overloads within 5 seconds on the 30mV and higher ranges. Up to 1200V peak may be applied momentarily on any range without damaging the instrument.

A ±1V at 1mA output is located on the rear panel for connection to recorders or other readout devices. Accuracy is ±2% of full scale at the meter and ±1% at the rear panel recorder output.

The 155 is designed for battery operation to minimize ground loop and high frequency pickup problems in sensitive voltage measurements. Four internally mounted standard batteries provide greater than 1000 hours of operation.

RANGE: ±1μV full scale to ±1000V on zero center meter in 19 overlapping 1× and 3× ranges.

ACCURACY: ±1% of full scale at recorder output, ±2% of full scale at meter, exclusive of noise and drift.

ZERO DRIFT: <0.5μV per 24 hours typically <0.1μV per °C. Long-term drift is non-cumulative.

METER NOISE: <0.03μV rms (0.15μV peak-to-peak) on most sensitive range with input shorted.

INPUT RESISTANCE: 100MΩ on 3V to 1kV ranges; 10MΩ on 300mV to 1V ranges, 1MΩ on 1μV to 100mV ranges.

NORMAL MODE REJECTION: An applied 50-60Hz signal which is 80dB greater than full scale peak-to-peak will not affect reading on most sensitive range (equivalent to 100dB NMRR). Rejection decreases to 20dB on the 10mV and higher ranges. Peak AC+DC must never exceed 1200V.

COMMON MODE REJECTION: Common mode voltage, DC or 50–60Hz, 120dB greater than full scale up to 1200V peak will not affect reading (equivalent to 140dB CMRR).

ISOLATION: $>10^{12}\Omega$ shunted by 0.01μF between chassis ground (case) and input LO at up to 50% relative humidity and 25°C.

RISE TIME (10%–90%): 1 second on 10μV range and above, increasing to 5 seconds on 1μV range.

ZERO SUPPRESSION: ±25μV.

RECORDER OUTPUT: ±1V at up to 1mA.

OVERLOAD: Up to 1200V peak may be applied momentarily on any range. Recovery from overload 10^6 times full scale for 1 second with 10kΩ source is within 5 seconds on the 30μV and higher ranges, increasing to 20 seconds on the 1μV range.

CONNECTORS: Output: Barrier strip. **Input:** Binding posts.

POWER: Four internally mounted carbon-zinc batteries (2N6) provide >1000 hours continuous operation. Barrier strip provided for external power supply.

DIMENSIONS, WEIGHT: 165mm high × 210mm wide × 185mm deep (6½ in. × 8¼ in. × 7¼ in.). Net weight 2.5kg (6 lbs.).

ACCESSORY SUPPLIED: Instruction manual.

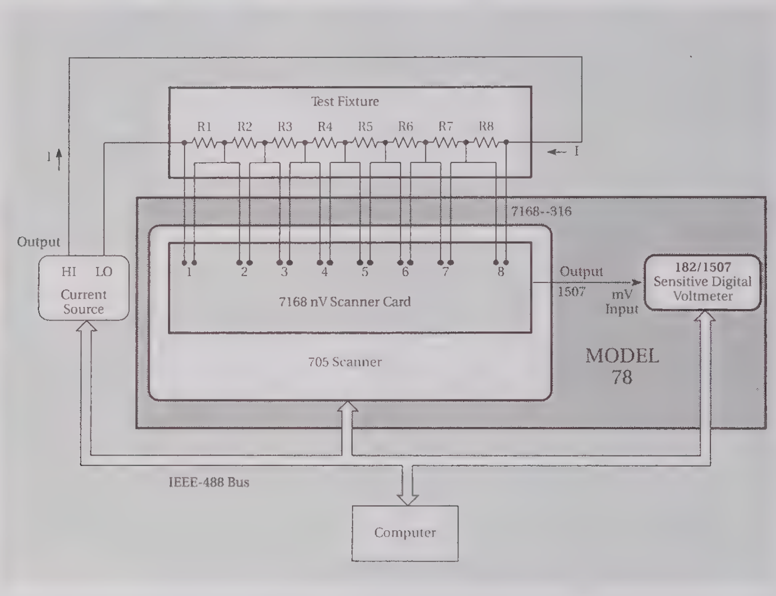
[illegible]

155
Null Detector/Microvoltmeter

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

See page 163 for descriptions of all accessories.

Model 78 Nanovolt Scanner Test System



The Model 78 provides all instrumentation and accessories necessary to scan eight channels of the Model 7168 Nanovolt Scanner Card and make low-level voltage measurements. The Model 78 includes:

- Model 7168 Nanovolt Scanner Card including all input cabling (page 127)
- Model 705 Scanner (page 112)
- Model 182/1507 Sensitive Digital Voltmeter (SDV) (page 68)

For applications such as thermocouple testing or low-resistance measurements including bus bar testing, low-resistance shunt measurements, and superconductor measurements, the Model 78 can be configured and programmed easily. The Model 705 Scanner controls the Model 7168 Nanovolt Scanner Card under supervision of the computer program. The Model 182 SDV measures the voltage across each sample as it is selected by the scanner. The resulting data are sent over the IEEE-488 bus to the computer for further computation.

262 Voltage Divider

- **Low thermal switching**
- **Input remote sense terminals**
- **Easy to operate**

ORDERING INFORMATION

262
Voltage Divider with Model 262-315 Low Thermal Cable, 0.9m (3 ft.)

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

See page 163 for descriptions of all accessories.

KEITHLEY 262 LOW THERMAL VOLTAGE DIVIDER
DIVIDER RATIO
POLARITY
WARNING: CONNECT CHASSIS TO EARTH
DO NOT EXCEED 20VDC INPUT

The Model 262 Low Thermal Voltage Divider offers a convenient method for nanovoltmeter calibration. It provides the necessary thermal stability as well as the accuracy to calibrate the most sophisticated nanovoltmeters (e.g., Model 181) and sensitive digital voltmeters (e.g., Model 182). In addition, it takes the burden out of calibrating today's µV-sensitive DMMs.

The Model 262 is the only instrument of its kind with the thermal stability critical for these applications. It is intended to be used with precision voltage sources found in any calibration or metrology lab.

DIVIDER RATIO	ACCURACY* (1 Year) 18°–28°C	TEMPERATURE COEFFICIENT (18°–28°C)	OUTPUT NOISE (1Hz BW)	THERMAL DRIFT**
10^2 : 1	± 35 ppm	2 ppm/°C	10 nV p-p	10 nV
10^3 : 1	± 35 ppm	2 ppm/°C	10 nV p-p	10 nV
10^4 : 1	±100 ppm	10 ppm/°C	1 nV p-p	3 nV
10^5 : 1	±100 ppm	10 ppm/°C	1 nV p-p	3 nV

*Referenced to output terminals.

**For ambient temp. changes ≤1°C/hour. Includes effects of supplied cable.

CONTROLS: Polarity, divider ratio.

INPUT RESISTANCE: 20kΩ for divider ratios of 10^2:1 and 10^4:1; 200kΩ for divider ratios of 10^3:1 and 10^5:1.

OUTPUT RESISTANCE: 2Ω for divider ratios of 10^4:1 and 10^5:1; 200Ω for divider ratios of 10^2:1 and 10^3:1.

OVERLOAD PROTECTION: Maximum operating input voltage is 20V. Input is protected against 1000V overloads from calibrators with current limits up to 150mA.

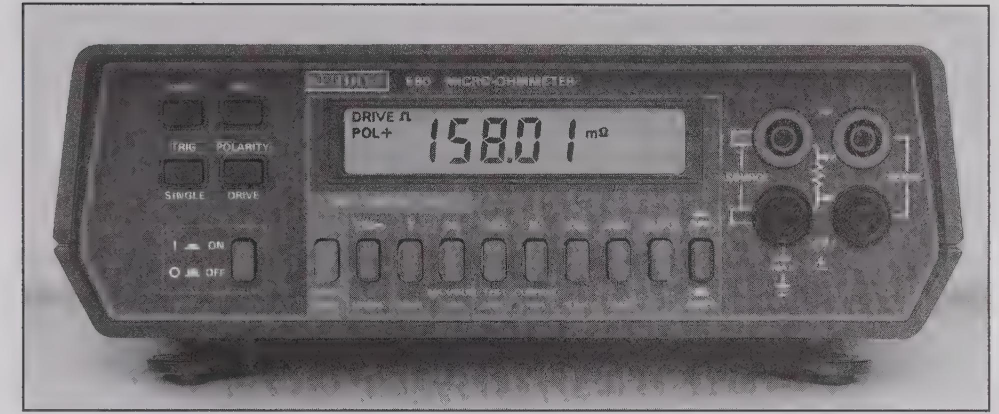
CONNECTORS: Input: 5-way binding posts for input, sense, case ground. **Output:** Special low thermal female connector; mates with 1506, 1507, 1481, 1482.

ENVIRONMENTAL LIMITS: Operating: 18°–28°C, 0 to 60% relative humidity. **Storage:** –25 to +65°C.

DIMENSIONS, WEIGHT: 114mm high × 165mm wide × 184mm deep (4½ in. × 6½ in. × 7¼ in.). Net weight 2kg (4½ lbs.).

ACCESSORY SUPPLIED: Model 262-315 low thermal male-to-male cable (3 ft.) for connecting to Model 181 or Model 182.

Micro-ohmmeter 580



- 10μΩ sensitivity
- 20mV voltage clamp
- Selectable test current waveforms
- 3 sets of test leads included
- Optional IEEE-488 interface

IEEE-488

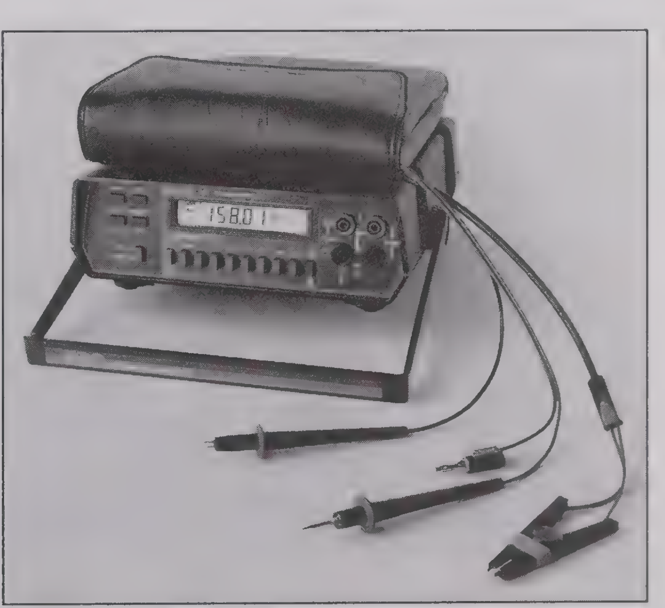
The 580 Micro-ohmmeter combines high accuracy, resolution, and sensitivity with three special capabilities that make micro-ohm measurements easier and more versatile than ever:

1. When measuring contact and connector resistances, it is important not to puncture oxides and films that may have formed. The 580 ensures this dry circuit condition by clamping the open circuit test voltage to 20mV on the 200mΩ, 2Ω, and 20Ω ranges when the 20mV MAX button is pressed.
2. The 580 can test more devices by enabling both test current polarity and waveform (DC or pulsed) to be selected. When using pulsed test current, the 580 automatically compensates for thermal EMFs. Tests on inductive devices are best performed using DC test current, as this avoids the effects of time constants on pulsed current resistance measurements. For temperature-sensitive components, a single trigger mode of operation minimizes power delivered to the device. Single trigger operation is possible via the front panel.
3. The optional IEEE-488 bus interface permits operation as a stand-alone unit as well as in a PC-based system.

A microprocessor-based design gives the 580 a number of advanced capabilities. Resistance measurements can be made from 10μΩ to 200kΩ on seven ranges, with 4½-digit resolution and accuracy to within 0.04% of reading. Ranging can be performed either manually or automatically. Settling time is less than one second to within 10 counts on a given range.

The 580 is supplied with three sets of test leads—standard leads, Kelvin probes, and Kelvin clip leads—in a rugged strap-on pouch. For applications requiring portability or line power isolation, an optional battery pack is also available. Digital calibration is possible through front panel controls or over the optional IEEE-488 bus interface.

The 580 is supplied with three sets of test leads—standard leads, Kelvin probes, and Kelvin clip leads—in a rugged strap-on pouch.



ORDERING INFORMATION

580
Micro-ohmmeter with 5804, 5805, 5806 Test Leads and 5801 Test Lead Pouch

580-1
Micro-ohmmeter without Test Leads and Pouch

580/5802
Micro-ohmmeter with Isolated Analog Output/IEEE-488 Interface

580/1978
Micro-ohmmeter with Rechargeable Battery Pack

580/02/78
Micro-ohmmeter with Isolated Analog Output/IEEE-488 Interface and Rechargeable Battery Pack

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS

5804	Test Lead Set
5805	Kelvin Probes, 0.9m (3 ft.)
5805-12	Kelvin Probes, 3.6m (12 ft.)
5806	Kelvin Clip Leads
5807-7	Helical Spring Point Test Leads

TEST FIXTURE

8003	Low Resistance Test Fixture

RACK MOUNT KITS

1010	Single Rack Mounting Kit
1017	Dual Rack Mounting Kit

OTHER

1755	Calibration Interface
1978	Rechargeable Battery Pack
5801	Test Lead Pouch
5802	Isolated Analog Output/IEEE-488 Interface

See page 163 for descriptions of all accessories.

Micro-ohmmeter

RANGE	RESOLUTION	MAXIMUM TEST CURRENT	NON DRY CIRCUIT TEST ACCURACY 1 Year, 18°–28°C ±(%rdg + counts)		DRY CIRCUIT TEST	
			PULSED	DC	MAXIMUM POWER DISSIPATION IN SAMPLE	ACCURACY 1 Year, 18°–28°C ±(%rdg + counts) PULSED
200 mΩ	10 μΩ	100 mA	0.04 + 2	0.04 + 3	500 μW	0.05 + 2
2 Ω	100 μΩ	10 mA	0.04 + 2	0.04 + 3	50 μW	0.05 + 2
20 Ω	1 mΩ	1 mA	0.04 + 2	0.04 + 3	5 μW	0.05 + 2
200 Ω	10 mΩ	1 mA	0.04 + 2	0.04 + 2		
2 kΩ	100 mΩ	1 mA	0.04 + 2	0.04 + 2		
20 kΩ	1 Ω	10 μA	0.05 + 2	0.05 + 2		
200 kΩ	10 Ω	10 μA	0.075 + 2	0.075 + 2		

CONFIGURATION: 4-wire (two sense, two source).

MAXIMUM SOURCE VOLTAGE: 20mV in Dry Circuit Test, 1V otherwise.

MAXIMUM TEST LEAD RESISTANCE

200mΩ and 2Ω Ranges: Up to 5Ω in each SOURCE lead and 10Ω in each SENSE lead with Non Dry Circuit Test; up to the selected full range resistance in each SOURCE lead and 10Ω in each SENSE lead with Dry Circuit Test.

20Ω through 200kΩ Ranges: Up to half of the selected range in each test lead.

CONVERSION RATE: 3 readings/second typical.

RANGING: Auto or manual.

AUTORANGING TIME: 200 ms. per range change, average.

SETTLING TIME: <1 second to within 10 counts on range.

MAXIMUM INPUT OVERLOAD: 10V limited to 10A.

MAXIMUM COMMON MODE VOLTAGE: 30V rms at DC, 50 or 60Hz.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

ISOLATED ANALOG OUTPUT/IEEE-488 INTERFACE (Model 5802 Option)

ANALOG OUTPUT

LEVEL: 1V = 10,000 counts on ×1 gain.
1V = 100 counts on ×100 gain.
Maximum output voltage = ±4V.

ACCURACY: ±(0.25% of displayed reading + 2mV). In ×100 , 2mV output = 0. 2 displayed counts.

RESPONSE TIME: Follows display conversion rate.

OUTPUT RESISTANCE: 1000Ω.

ISOLATION: ANALOG OUTPUT LO is connected to IEEE COMMON. Maximum common mode voltage from IEEE COMMON to earth ground is 30V rms at DC, 50 or 60Hz.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, SDC, GET, GTL UNT, UNL, SPE, SPD, LLO.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, DRY CIRCUIT TEST, Operate, RELative, POLARITY, DRIVE, TRIGger, Calibration, EOI, SRQ, Status, Data Format, Terminator.

GENERAL

DISPLAY: ±20,000-count LCD, range and status information displayed.

OVERRANGE INDICATION: "OL" displayed.

CONNECTORS: Measurement and rear panel EXTERNAL TRIGGER inputs: Banana jacks.

RELative: Allows zeroing of on-range readings. Allows readings to be made with respect to baseline value. Display annunciator indicates REL.

DRIVE: Selects either pulsed or DC SOURCE current. Pulsed drive provides automatic cancellation of thermal offsets, using 50% duty cycle pulse. Display annunciator indicates drive selected.

POLARITY: Selects either positive or negative SOURCE current in either drive. Display annunciator indicates polarity selected.

TRIGger: Allows single pulsed measurements.

OPERATING ENVIRONMENT: 0°–50°C, <80% relative humidity up to 35°C; linearly derate 3% R.H./°C from 35° to 50°C.

STORAGE ENVIRONMENT: –25° to 60°C.

POWER: 105–125V or 210–250V (switch selected), 90–110V available. 50–60Hz, 12VA. Optional 6-hour battery pack, Model 1978.

DIMENSIONS, WEIGHT: 89mm high × 241mm wide × 300mm deep (3½ in. × 9½ in. × 11¾ in.). Net weight 3.2kg (7 lbs.). Test lead pouch adds 76mm (3 in.) in height.

ACCESSORIES SUPPLIED: Models 5801, 5804, 5805, and 5806 test leads; Operator's and Service Manuals.

ANALOG OUTPUT
IEEE-488 INTERFACE
WARNING

Semiconductor Measurements

Introduction 76

I-V MEASUREMENTS

251
I-V Test Software 77

2361
Trigger Controller Unit 82

236, 237, 238
Source-Measure Units 84

C-V MEASUREMENTS

Model 82
C-V System 88

5958
C-V Software Utilities 91

595
Quasistatic C-V Meter 93

590
C-V Analyzer 96

5905, 5906, 5907, 5909, 5955
Calibration Sources 100

HALL EFFECT MEASUREMENTS

Overview 101

705/7065
Hall Effect Card/Scanner 102

Model 80
Hall Effect System 103

925A, 925B
Hall Effect Systems 104

926A, 926B
Differential Hall Effect Profilers 104

220/617
High Impedance Hall Effect System 108

Introduction

An Introduction to Semiconductor Measurement Solutions

Keithley Instruments has a variety of instruments and systems uniquely suited to the needs of the semiconductor test industry. Our semiconductor measurement products can make the critical difference in your research, assess the quality of bulk semiconductor materials, lead the way to increased product reliability, or keep your production line running.

Complete Solutions

Keithley offers complete solutions for I-V, C-V, and Hall Effect, including:

	I-V	C-V	Hall effect
Systems & Test Control Software	251	82 (5956, 5957), 5958	80, 925/926
Instruments	236, 237, 238	590, 595	7065
Related System Accessories	2361, 213	5951, 230-1	196, 220, 485/4853, 181
Switching Products	7072, 7072-HV, 7073, 7158, 7153	7072, 7072-HV, 7073, 7158, 7153	7168
Test Fixtures	8006, 8007	8006, 8007	925-BC sample holders for 925/6 (set of 10)

Innovative Solutions—Designed for Semiconductor Test

We combine forty years of superior design experience with leading edge technology to develop innovative and complete solutions for satisfying semiconductor measurement needs. Recent advances unparalleled in the semiconductor test industry include:

- Glitch-free single channel SMUs with outputs to 1100V or 1A, and 1ms total source-measure time per sample.
- PC-based I-V test software for curve tracing and semiconductor characterization.
- "Feedback charge" quasistatic C-V technique.
- Simultaneous C-V technique.
- Hall Effect instrumentation available as system components and as complete systems suitable for both high- and low-resistivity materials.

Our products are optimized for semiconductor characterization—with many features not available from general purpose products—to increase measurement integrity and give you results fast. For instance:

- Fully floating SMUs with remote sense (4-wire) and guarding achieve 1ms threshold voltage measurements, 10fA sensitivity, and 0.03% basic measurement accuracy.
- I-V test software includes Test Library containing over 20 of the most important I-V tests, including curve families and DC parameter measurements on bipolars, FETs, diodes, resistors, and capacitors.
- The only quasistatic C-V meter with real time leakage current measurement and correction.
- High frequency C-V analyzer with cable correction, 15mV rms test signal, 1000 point/s C-t and built-in analysis.
- C-V system software for DIT, doping, bias temperature stress testing, and Zerbst minority carrier lifetime testing.
- DC Hall and van der Pauw measurements with superior sensitivity and precision available with dual temperature (77K and room temperature) and differential (etching) measurement capability.

System Solutions

All these innovative products are available as system components, with expert applications assistance readily available to assist you in the design and configuration of your test system. They are also easy to order as complete systems, such as the Model 82 for C-V, Model 251-based I-V systems, or the Model 80, 925 and 926 for Hall Effect testing. Our test fixtures, cables, adapters, and other accessories have been specially designed to deliver the superior performance of Keithley's instrumentation to the device-under-test.

Keithley Systems Division can provide fully integrated turn-key parametric test systems when your testing requirements include parametric test or in-line process monitoring. The Systems Division provides the hardware, software, and support services necessary to meet the most exacting process monitoring demands.

Applications Assistance

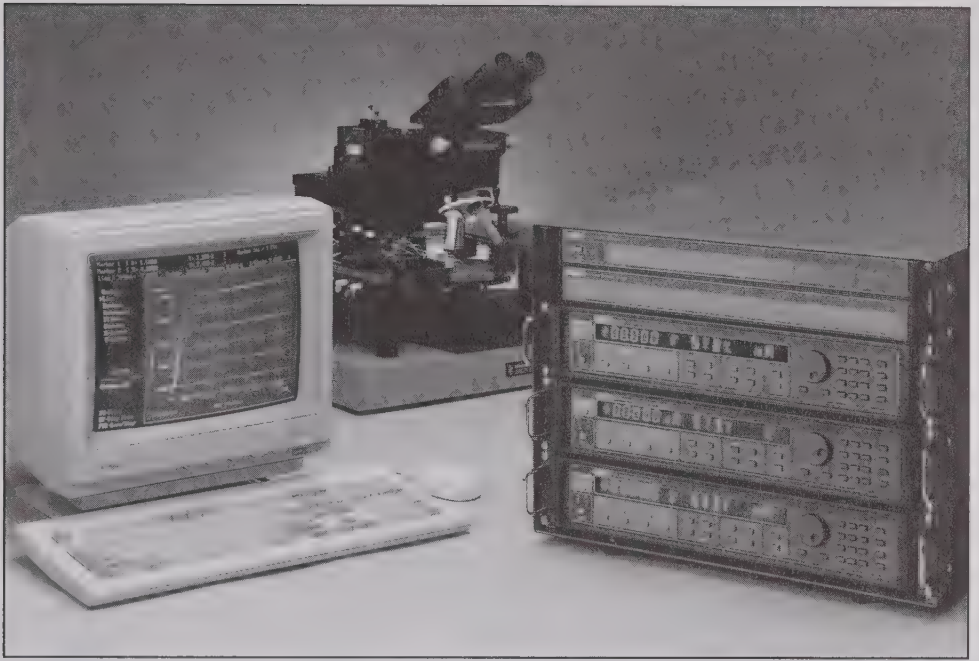
Discuss your semiconductor characterization requirements with professionals who know Keithley's products best, the Keithley applications engineers. Rely on our experienced engineers to select the instrumentation that suits your application. Then call on their product expertise to get you up and running quickly. Call our toll-free number,

1-800-552-1115

8:00 A.M. to 7:00 P.M. Eastern time (U.S. only).

I-V Test Software

251



- **Interactive I-V test**
- **Sensitivity to 10fA and 10μV**
- **Powerful user interface**
- **Control any GPIB device**
- **Extensive test library**

Interactive Testing

The Model 251 I-V Test Software offers interactive testing of current vs. voltage (I-V) in the research and development of semiconductor devices, processes and materials, and for component evaluation. The 251 utilizes Keithley's Source-Measure Units (SMUs) to measure and display device characteristics such as I-V curve families, breakdown voltage, leakage current, DC or differential gain, and resistance, at currents from 10fA to 1A and voltages from 10μV to 1100V.

The 251 adds an interactive user interface and graphic display to single SMU applications. Its test setup table makes it easy to program the SMU and save the data to reproduce results at any time. On-screen interactive analysis permits quantitative interpretation of acquired data and qualitative assessment of curve shapes.

The 251 can also integrate up to six SMUs into semiconductor parameter analysis and curve tracing systems. These SMUs offer the industry's fastest source-measure times at 1ms, plus sophisticated triggering for I-V curve family tests and DC source-measure tests. This versatile software package takes full advantage of the SMU capabilities, plus offers complete characterization of devices and comprehensive analysis of test results, without programming or knowledge of GPIB commands.

Simplifying Control

The 251 has been structured to ease I-V testing by providing a fast, versatile user interface to all test parameters, display formats, and GPIB controls. Tests are defined by one convenient fill-in-the-blank form that simplifies setup and execution. Once the desired values of Sweep, Step and Bias output are selected, the 251 is ready to acquire data, using autoranging and default settings to set other test parameters. Custom setting of test parameters is available for more demanding applications.

Executing a test is easy. The software automatically interprets the test form parameters, translates them into GPIB commands, sends them to the test instrument and retrieves the data. Tests and data can be saved in any directory or on floppy disk. A context-sensitive help screen explains all features and function keys.

Displaying Results

The graphic display capabilities offer speed and versatility in reporting test information. Data can be displayed either as a list, an X-Y graph, or an X-Y-Y graph. Complete control of the display format is built into the 251 to eliminate ambiguity in test results. Formatting selections include Title, Axes Labels and Scaling, Autoscale, Grid Type and Color, Axis Inversion and Gain calculations.

Powerful analysis capabilities allow curves to be displayed and interactively analyzed using Filtering, Zoom, Markers and Line Display. Dual Markers derive X-Y data point readouts to extract values from the curves. The Line function measures the slope and intercept values of a curve to derive resistance, threshold voltage, mobility, gain and other device parameters.

[illegible]

251
I-V Test Software for Models 236, 237, 238 (requires 2361 Trigger Controller Unit for multiple SMU usage)

251/2361
I-V Test Software with Trigger Controller for Models 236, 237, 238

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

251 I-V Test Software

FUNCTION KEYS

All major functions are accessed by simply pressing the appropriate function key or using a mouse.

F1 **ON-LINE HELP** provides an explanation of any feature without consulting the instruction manual.

F4 **PRINT** data list, I-V curve families or setup forms to document test procedures and results. Acquired curves can also be output to an HPGL plotter for publication-quality graphs.

F5 **GPIB CONTROL** of any device on the bus allows control of test conditions such as switch matrix settings and monitoring of system status.

F7 **DISPLAY SETUP** is completely selectable using the convenient fill-in-the-blank Display Setup Form. It also permits on-screen display of DC or differential gain.

F7 **DISPLAY** the results without executing the test again, even if Display Setup parameters were changed.

F10 **EXECUTE** the Curve Family or DC Source Measure TEST presently displayed.

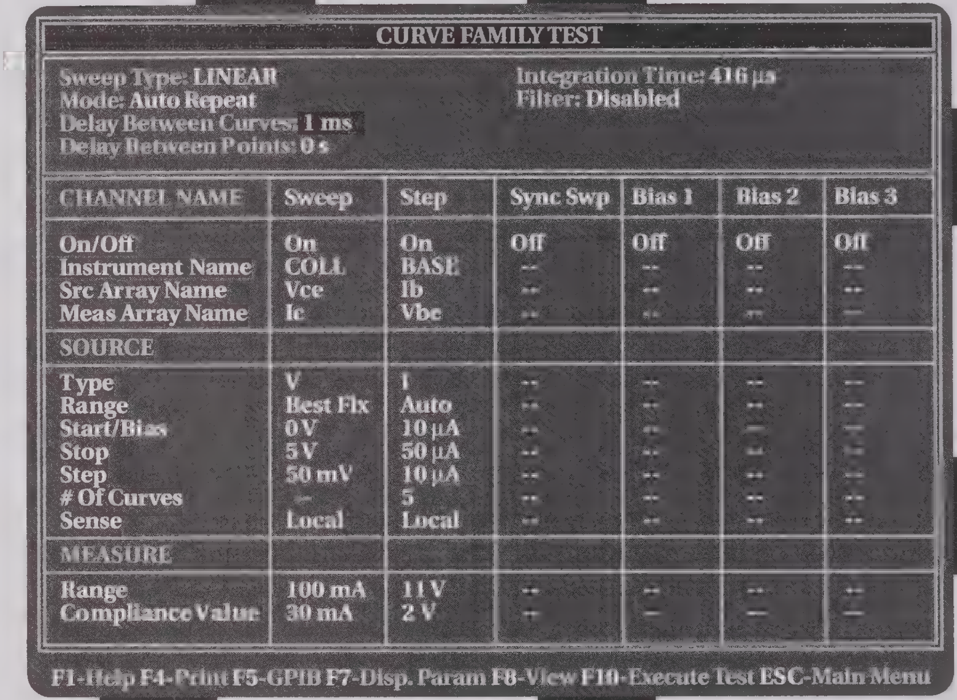
ON-LINE HELP

F1 HELP

HARDCOPY

F4 PRINT SCREENS

TEST SETUP FORM



CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Auto Repeat
Delay Between Curves: 1 ms
Delay Between Points: 0 s
Integration Time: 416 µs
Filter: Disabled

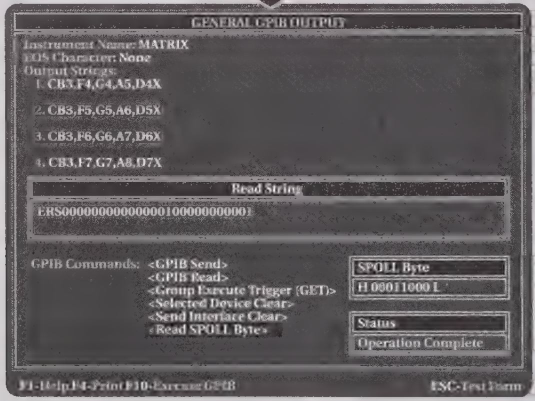
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLL	BASE	--	--	--	--
Src Array Name	Vce	Ib	--	--	--	--
Meas Array Name	Ic	Vbc	--	--	--	--
SOURCE						
Type	V	I	--	--	--	--
Range	Best Fix	Auto	--	--	--	--
Start/Bias	0 V	10 µA	--	--	--	--
Stop	5 V	50 µA	--	--	--	--
Step	50 mV	10 µA	--	--	--	--
# Of Curves	--	5	--	--	--	--
Sense	Local	Local	--	--	--	--
MEASURE						
Range	100 mA	11 V	--	--	--	--
Compliance Value	30 mA	2 V	--	--	--	--

F1-Help F4-Print F5-GPIB F7-Disp. Param F8-View F10-Execute Test ESC-Main Menu

F5 CONTROL OTHER GPIB DEVICES

F7 SPECIFY GRAPHIC FORMAT

GPIB CONTROL



GENERAL GPIB OUTPUT

Instrument Name: MATRIX
EOS Character: None
Output Strings:
1. CB3,F4,G4,A5,D4X
2. CB3,F5,G5,A6,D5X
3. CB3,F6,G6,A7,D6X
4. CB3,F7,G7,A8,D7X

Read String
ERS000000000000000100000000001

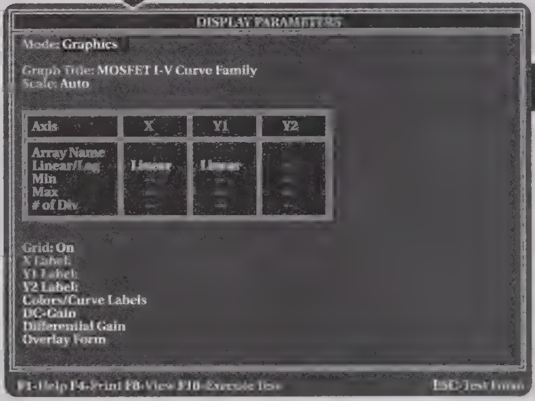
GPIB Commands: <GPIB Send>
<GPIB Read>
<Group Execute Trigger (GET)>
<Selected Device Clear>
<Send Interface Clear>
<Read SPOLL Byte>

SPOLL Byte: H 00011000 L

Status: Operation Complete

F1-Help F4-Print F10-Execute GPIB ESC-Test Form

DISPLAY SETUP



DISPLAY PARAMETERS

Mode: Graphics

Graph Title: MOSFET I-V Curve Family
Scale: Auto

Axis	X	Y1	Y2
Array Name	--	--	--
Linear/Log	Linear	Linear	--
Min	--	--	--
Max	--	--	--
# of Div	--	--	--

Grid: On
X Label:
Y1 Label:
Y2 Label:
Colors/Curve Labels
DC-Gain
Differential Gain
Overlay Form

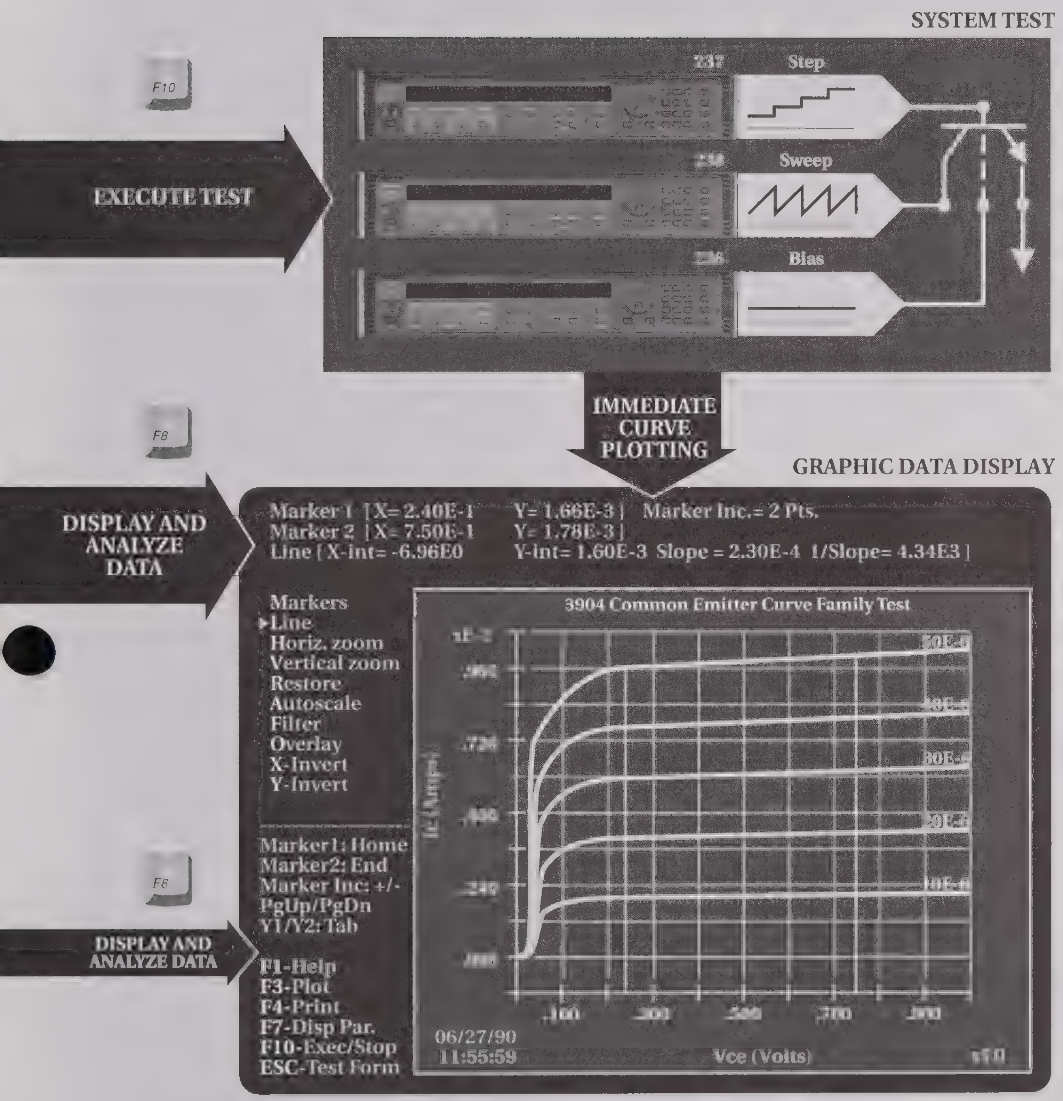
F1-Help F4-Print F8-View F10-Execute Test ESC-Test Form

ESC Remaining functions are selected from the main menu by pressing ESC. These include FILE to save or load data and data EXPORT in LOTUS 1-2-3 format.

I-V Test Software 251

SIMPLE OPERATION

The Test Setup Form is the central operation point for the Model 251. From here, operators can assign a specific SMU to each channel, and select which channels should measure by specifying data array names. Choose the appropriate Start and Stop settings for the device and set the remaining parameters using customized or standard default values. Then select Auto Repeat to acquire and display continuously, or Single Test to run the test once.

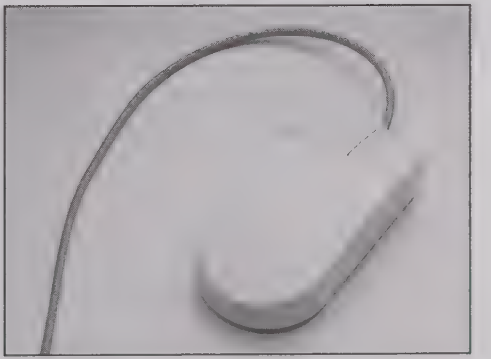

SYSTEM TEST
F10
EXECUTE TEST
237
Step
238
Sweep
236
Bias
IMMEDIATE CURVE PLOTTING
F8
GRAPHIC DATA DISPLAY
DISPLAY AND ANALYZE DATA
F6
DISPLAY AND ANALYZE DATA
3904 Common Emitter Curve Family Test
xE-2
.960
.720
.480
.240
.000
Ic (Amps)
50E-6
40E-6
30E-6
20E-6
10E-6
.100
.300
.500
.700
.900
Vce (Volts)
xE0
Markers
Line
Horiz. zoom
Vertical zoom
Restore
Autoscale
Filter
Overlay
X-Invert
Y-Invert
Marker1: Home
Marker2: End
Marker Inc: +/-
PgUp/PgDn
Y1/Y2: Tab
F1-Help
F3-Plot
F4-Print
F7-Disp Par.
F10-Exec/Stop
ESC-Test Form

```
Marker 1 [X= 2.40E-1     Y= 1.66E-3]   Marker Inc.= 2 Pts.
Marker 2 [X= 7.50E-1     Y= 1.78E-3]
Line [X-int= -6.96E0     Y-int= 1.60E-3  Slope = 2.30E-4  1/Slope= 4.34E3]
```

06/27/90
11:55:59

MOUSE CONTROL

Optional use of a mouse can enhance the 251's flexible control.



I-V Test Software

The Model 251 I-V Test Software also allows accurate comparison with reference data or HI-LO limits, by overlaying previously acquired or imported curves on the graphic display to immediately evaluate data against known criteria. When more complex analysis is required, the 251's Data Export can send test results to spreadsheets, databases, SPC programs, and many other DOS software applications, including Keithley's ASYST scientific software.

Quick Test Libraries

A library of 25 standard tests is supplied with the Model 251 for the most popular component tests, diode tests, bipolar transistor tests, FET tests, and others (see the complete list in the Specifications). To accommodate unique testing requirements, these standard tests may be modified and saved to build your own personal test library.

Application Versatility

The Model 251 performs all of the most common I-V tests using Keithley SMUs. It can also control other GPIB devices, including additional bias sources, switching matrix, hot chuck, or semi-automatic probe station without interrupting the I-V test session. Tests that are easily accomplished with the 251 include:

Bipolar Transistors
I_C-V_{CE} Curves
V_{SAT}, h_{FE}, Beta, R_B
BV_{CEO}, I_{CEO}
Gummel Plot
Beta-I_C Curve

MOSFETs and JFETs
I_D-V_{DS} Curves
I_D-V_{GS} Curves
V_{TH}, g_m, Mobility
BV_{DSS}, I_{GSS}, $R_{DS(ON)}$
Sub-Threshold Plot

Diodes
I_F-V_F Curves
V_F, I_F, R_F
I_R, V_Z
Protection Diode Leakage

Other Components
Analog Opto Gain
Capacitor Leakage
Tunneling Current
Linear IC Parameters

Materials
Sheet Resistance
Volume Resistivity
Surface Resistivity

Wafer Level Test Structures
Contact Chain Resistance
Gate or Field Capacitors
Memory Cell Leakage

Source and Measurement Integrity

Keithley's Models 236, 237, and 238 Source-Measure Units (SMUs) provide the instrumentation hardware that makes this I-V system versatile and accurate. The Model 251 I-V Test Software integrates up to six SMUs into flexible, cost-effective systems that address applications from two-terminal device testing to complete wafer level device characterization.

Each SMU is capable of sourcing and measuring breakdown voltage up to 1100V and transistor channel or diode forward current up to 1A. These units also offer 10fA and 10µV sensitivity, 0.03% basic accuracy, 0.001% noise, and source and measure times as fast as 1ms.

Keithley SMUs can simultaneously source voltage and measure current or source current and measure voltage. Virtually any I-V test can be performed by simply connecting one SMU to each pin of the Device-Under-Test (DUT). Each SMU functions as four instruments in one: electrometer, DMM, current source, and voltage source. This replaces several individual instruments and switches for better signal integrity, higher reliability, simpler connections, and lower cost.

The option to configure one to six SMUs provides flexibility in selecting the optimum combination of standard, high voltage, and high current SMUs to meet specific application requirements without sacrificing measurement integrity.This system can be easily upgraded by adding SMUs as application or measurement requirements change.

SMU Capabilities

- **1100V, 1A output capability.**
- **10fA, 10µV sensitivity.**
- **1ms source/measure time.**
- **0.03% accuracy and 0.001% noise.**
- **Four-wire remote sense for accurate high current and low resistance testing.**
- **Full floating SMU architecture for fast, accurate self-biased threshold voltage or Beta testing.**
- **Selectable integration time, averaging, linear or log sweeps, and fixed or auto ranging to optimize speed/accuracy.**

I-V Test Software

OVERVIEW

INSTRUMENTS CONTROLLED: Model 236/237/238 Source Measure Units (SMU). Model 2361 Trigger Controller is required for multiple SMUs.

TESTS: Control instruments to source and measure current or voltage.

Curve Family: SWEEP, SYNCH SWEEP, STEP, and up to 3 BIAS channels, Linear or Log sweep.

DC Source-Measure: Up to 6 BIAS Channels.

GPIB CONTROL: Provides basic control of non-SMU instruments. Useful for controlling sources, switch matrices, and hot chucks.

DATA DISPLAY: Graphic or list display.

XY or XYY Graph Axes: Manual or auto scale, linear or log, labeled, X-axis and Y-axis invert.

Overlay two sets of reference data on original.

GRAPHIC ANALYSIS: Dual data curve markers with data value readout.

Line Display: Between markers. Readout slope, 1/slope, X- and Y-intercept. Zoom between markers. Filter data curve.

Gain/Ratio Calculation: DC or differential. Data array or point. Graphic display or readout referenced to marker position. Used for Beta, g_m or resistance.

PRINT/PLOT: Hardcopy output of any screen to printer, or output graphic display to plotter.

FILES:

Data File: Data, test, GPIB and display parameters.

Test Setup File: Test, GPIB and display parameters.

Instrument Configuration File: Instrument names, GPIB addresses, Trigger Controller channels.

Lotus File (WK1): Data, array names and units. Data import/export.

MEASUREMENT CAPACITY LIMITS: A curve in the Curve Family Test is limited to 1000 points. Up to six source arrays and up to six measurement arrays can be created by each test. Each array is limited to 4000 points and each test is limited to 8000 points. The maximum number of arrays and tests is limited only by the available disk storage space.

HELP: On-line, context sensitive, with index.

SYSTEM REQUIREMENTS

RECOMMENDED HOST COMPUTER: IBM compatible 80386, 640kB RAM, 1MB of LIM expanded memory, hard drive, 720kB 3½ inch or 1.2MB 5¼ inch floppy drive, Intel 80287 or 80387 math coprocessor, Microsoft or Logitech mouse, VGA color monitor and graphics card.

MINIMUM HOST COMPUTER: IBM-AT or compatible, 640kB RAM, 384kB of LIM expanded memory, hard drive, 720kB 3½ inch or 1.2MB 5¼ inch floppy drive, Intel 8087 math coprocessor, EGA color monitor and graphics card.

OPERATING SYSTEM: MS-DOS or PC-DOS 3.2 (minimum).

GRAPHICS ADAPTER: EGA or VGA color, VGA monochrome.

IEEE-488 (GPIB) INTERFACE CARDS SUPPORTED

Advantech PCL 748

B&C PC488A

BBS GPIB-1000

Capital Equipment PC<>488, 4×488, PS<>488

Contec GPIB (PC)

Hewlett Packard HPIB

IBM GPIB board

ICS 488-PC1

IOtech GP488, GP488/2

Keithley PC-488-CEC, 4-488-CEC-0M, 4-488-CEC-1M, PS-488-CEC

Keithley MetraByte IE-488

National Instruments GPIB-PC, GPIB-PCII, GPIB-PCIIA, GPIB-PCIII, MC-GPIB

Qua Tech MXI-100, MXI-1000

Scientific Solutions IEEE 488 LM, MC-IEEE 488

Ziatech ZT 1444, ZT/2

COMPATIBLE PRINTERS: IBM Graphics Printers, Epson or compatible, HP LaserJet, IBM Proprinter, and Okidata Microline 182.

COMPATIBLE PLOTTERS: HP7440, HP7470, HP7475.

COMPATIBLE MOUSE: Microsoft or Logitech.

SUPPLIED TEST LIBRARY

The Test Library provides default settings for the Test, GPIB Control, Data Display and Graphic Analysis screens.

FET TESTS: Curve Family, Threshold Voltage, Transconductance, Breakdown, and Leakage.

BIPOLAR TESTS: Curve Family, Gummel Plot, Current Gain, Breakdown, and Leakage.

DIODE TESTS: I-V Curve, Reverse Breakdown, Zener Voltage, Zener Resistance.

COMPONENT TESTS: Capacitor Leakage, Resistor Voltage Coefficient.

EXAMPLE GPIB CONTROL: 213 Quad Voltage Source, 707 Switching Matrix and hot chuck.

MATERIALS PROVIDED

Instruction Manual

Diskettes: 720kB 3½-inch and 1.2MB 5¼-inch containing installation, program, test library, and sample data.

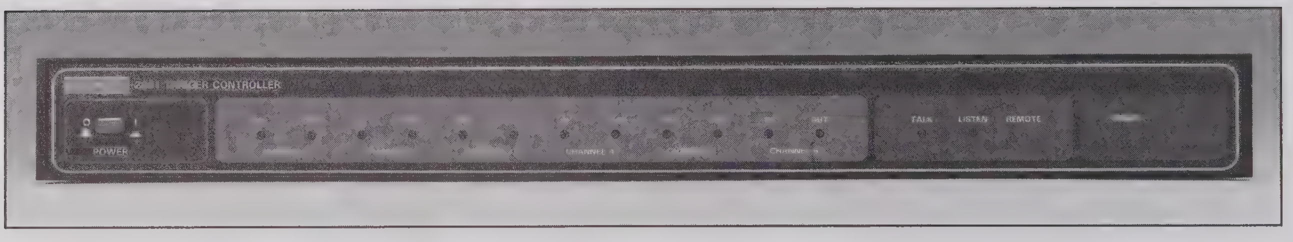
ORDERING INFORMATION

251
I-V Test Software for Models 236, 237, 238 (requires 2361 Trigger Controller Unit for multiple SMU usage)

251/2361
I-V Test Software with Trigger Controller for Models 236, 237, 238

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

2361 Trigger Controller Unit



- **Improve system throughout**
- **Trigger up to six instruments**
- **Automatic routing of TTL signals**
- **Speed operation of multiple Source-Measure Units**

IEEE-488

ORDERING INFORMATION

2361
Trigger Controller Unit with 7051-2 BNC Interconnect Cable, 0.6m (2 ft.)

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

Description

The Model 2361 Trigger Controller Unit (TCU) puts TTL trigger routing and coordination under GPIB control for rack and stack systems. This compact unit connects to the trigger inputs and outputs of up to six instruments using BNC cables. All triggers in the system are passed through the 2361 Trigger Controller to allow:

- Automatic routing of triggers between inputs and outputs.
- Advanced coordination among instruments using "AND", "OR" and simultaneous triggering.

Applications

The 2361 is designed to control test systems of two to six Source-Measure Units (SMUs) or other GPIB instruments. It is used to coordinate interactions between instruments, including source settling, measurement, and switch closure changes. The non-volatile program memory permits system synchronization remote from any GPIB controller.

Automatic Trigger Routing

The 2361 TCU allows trigger input and output signals from instruments in a test system to be arbitrarily directed to one another without changing cable connections. For example: to "route" a trigger received on input 1 to output 2, the 2361 TCU would be programmed with "1>2". Trigger routing allows complete flexibility in test design with reduced operator intervention and without sacrificing the speed and synchronization provided by TTL triggers. Each TCU can trigger up to six separate GPIB instruments.

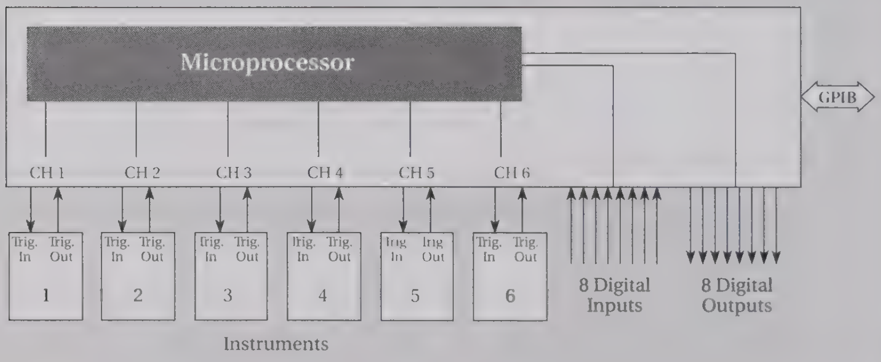
Advanced Triggering Capabilities

The 2361 Trigger Controller Unit adds capabilities beyond those possible with manual trigger cable connections. Six trigger relations may be programmed using GPIB commands to specify which trigger inputs will result in a particular group of outputs. "OR" causes a trigger output when a trigger is received on any one of the channels specified. "AND" will accumulate triggers until one has been received on each of the channels specified and then will generate the trigger outputs. This is especially useful for allowing multiple sources or SMUs in a test system to settle concurrently, then multiple meters or SMUs to measure in unison. The result is two to ten times faster test execution than with serial trigger loops.

In test systems that incorporate instruments from several different manufacturers, the 2361 TCU can interface triggers with falling and rising edge directions to one another.

Coordination of Non-GPIB Systems

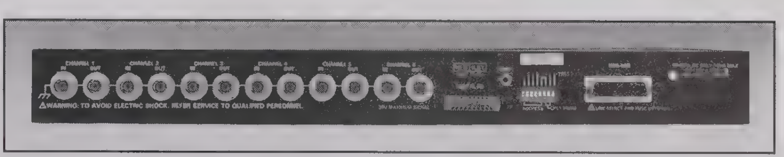
The TCU can store three programs in non-volatile memory. At power-up, one of these programs is loaded, as chosen by rear panel switches. The desired relations are set up with a GPIB controller and stored; then the 2361 TCU can be installed in a system with no GPIB controller to provide trigger coordination.



Trigger Controller Unit 2361

Digital I/O for System Monitoring and Control

A digital I/O port provides 8 bits of TTL inputs and 8 bits of TTL outputs. SRQs may be generated by changes in the digital or trigger inputs.



OVERVIEW

TRIGGER CONTROLLER: Provides control of trigger pulses among up to six instruments. The manner in which the trigger signals are modified is programmable over the IEEE-488 bus. Includes 8-bit digital I/O port.

FUNCTION: Can be used to synchronize triggers from different instruments in a measurement system. A simple trigger programming language provides the flexibility to control instrument operation in a variety of ways.

TRIGGER I/O PROGRAM: Up to six input-output relations constitute the program which resides in internal memory. Non-volatile storage of up to three trigger I/O programs.

TRIGGER INPUT EXPRESSIONS: Specify what combinations of trigger inputs will cause a trigger output. Two operators are used in trigger input expressions:

+	Same as the Boolean "OR" operator.
*	"Cumulative AND" operator. The input expression evaluates true when the triggers on both sides of all operators have been received.

TRIGGER OUTPUT EXPRESSIONS: Specify what combination of trigger outputs will occur after its input expression has evaluated true.

SIGNALS

CONFIGURATION:
Six trigger inputs, TTL compatible.
Six trigger outputs, TTL compatible.
One 8-bit digital input port, TTL compatible.
One 8-bit digital output port, TTL compatible.

TRIGGER CHANNELS:
Input: May be programmed to detect rising or falling edges.
Output: Active low pulse, maximum pulse width 110μs.
DIGITAL I/O:
Input: May be programmed to detect level or edges (either rising or falling).
Output: Specified level appears on digital output lines.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, SDC, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL2, PP0, DC1, DT0, C0, E1.

SRQ OPTIONS: SRQ on any of the following events: Trigger input detected, digital input detected, ready for IEEE-488 command, error.

PROGRAMMABLE FUNCTIONS: Trigger I/O programming, trigger I/O program initialization, trigger I/O program storage and retrieval, trigger input edge polarity, trigger response enable/disable, trigger latch initialization, trigger output generation, digital output specification, digital input edge polarity, SRQ masking, IEEE-488 holdoff, IEEE-488 output terminator, system status readback, factory default reset.

IEEE-488 address is set manually from the rear panel.

EXECUTION SPEED

INPUT PULSE WIDTH: 50ns minimum, unlimited maximum.

CHANNEL SYNCHRONIZATION (typical): Output pulses are synchronized to within 5ns.

TRIGGER PROPAGATION DELAY (IEEE-488 inactive): 350μs maximum, 100μs typical (T0D0, only one trigger I/O relation evaluates true).

PULSE RECOGNITION RATE: 2kHz maximum at any trigger input.

RESPONSE TO IEEE-488 COMMAND:
Trigger Control Commands: 2.5ms maximum.
Trigger I/O Program: 25ms maximum.

GENERAL

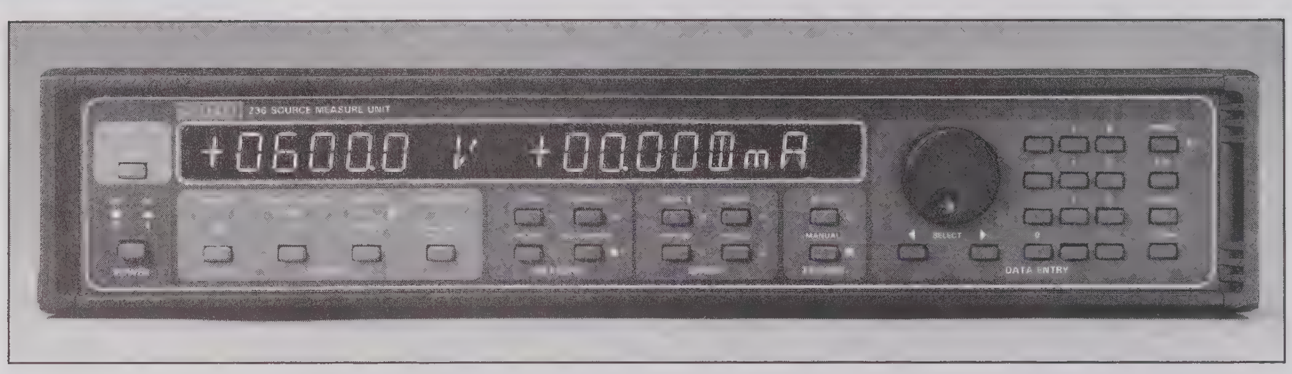
CONNECTORS:
Trigger Input, Output: Six BNC connectors each on rear panel.
Digital I/O: 20 pin card edge.

ENVIRONMENT: **Operating:** 0°-50°C; 0-70% R.H.
Storage: –25° to 65°C.

POWER: 90–125 or 180–250V AC (internal switch selectable); 50–60 Hz. 10VA max.

DIMENSIONS, WEIGHT: 425mm wide × 45mm high × 309mm deep (16¾ in. × 1¾ in. × 12 in.). Net weight 2.7kg (6.2 lbs.).

Source-Measure Units



- **Four instruments in one (voltage source, voltage measure, current source, current measure)**
- **10fA, 10μV measurement sensitivity**
- **1100V source and measure (237 only)**
- **1A source and measure (238 only)**
- **Standard and custom sweep capability including pulse**
- **1000 source/ measurements per second**
- **Four quadrant source operation**
- **Internal 1000-reading memory**

IEEE-488

[illegible]

236
Source-Measure Unit with two 7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft.) and one 236-ILC-3 Interlock Cable, 3m (10 ft.)

237
High Voltage Source-Measure Unit with two 7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft.) and one 236-ILC-3 Interlock Cable, 3m (10 ft.)

238
High Current Source-Measure Unit with two 7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft.) and one 236-ILC-3 Interlock Cable, 3m (10 ft.)

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

The 236, 237 and 238 Source-Measure Units (SMU) are fully programmable instruments, capable of sourcing and measuring voltage or current simultaneously. These systems are really four instruments in one; voltage source, current source, voltage measure and current measure.

The 236 will source voltage from 100μV to 110V, and current from 100fA to 100mA. It can also measure voltage from 10μV to 110V and current from 10fA to 100mA. The 237 offers the same capabilities with a decade enhancement in voltage source and measure (1100V). In this higher voltage range, current source and measure is 10mA maximum. The 238 offers a decade enhancement in current source and measure (1A). In this higher current range, voltage source and measure is 15V maximum.

The 236, 237 and 238 will measure very small currents and voltages. With current sensitivity of 10fA, measurement capabilities are equal to those of an electrometer. Selectable integration and the filtering of multiple measurements enhances sensitivity for demanding applications.

Both source voltages and source currents settle to specified accuracy in as little as 500μs. Programmable delay and fast, integrating measurement capability can provide coordinated source-measure times of 1ms.

Applications

These instruments address a wide variety of applications, including the characterization of semiconductor devices, and measurement of leakage currents or resistivity. They are particularly useful as source and measuring instruments in automated test equipment (ATE).

The 236, 237 and 238 provide simple, accurate measurements in semiconductor applications. Multiple units controlled with a personal computer make a powerful semiconductor parameter analyzer. Non-standard tests are also performed efficiently because of the unique versatility of these units.

Two accessory semiconductor test fixtures maintain the signal integrity of the SMUs all the way to your device. The 8006 is a general purpose test fixture, and the 8007 is designed to accommodate either 24- or 48-pin devices. These test fixtures can be safety interlocked with the 236, 237 and 238 to prevent accidental shock.

A Keithley Model 707 switching matrix and semiconductor switching cards may be used in conjunction with the 236, 237 and 238 for optimum performance in automated semiconductor measurement applications.

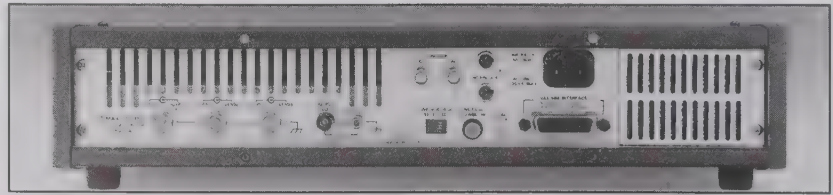
Keithley SMUs are powerful tools for research and industrial test applications. The short setup time and simplified programming are big advantages for tests that need to be up and running quickly. The overall versatility is ideal for constantly changing research use.

The large dynamic range of source and measure capabilities permits accurate measurement of insulation resistance, leakage current, and dissipation factors. The high sensitivity of these units make them ideal for characterizing the electrical properties of many materials.

Enhanced System Versatility

A single Source-Measure Unit eliminates most of the complicated system integration problems involved with setting up and programming individual sources and meters. This new, compact module also saves rack space, and can be more economical than separate components.

New test systems can be developed much faster with SMUs. There is only one set of device dependent commands (DDC) to learn, and the overall test system is better coordinated for more efficient operation.



Measurements as a Function of Voltage, Current, or Time

Measurements can be taken and recorded in an internal memory along with corresponding values of the source voltage or current and time. Up to 1000 values of each variable, correlated in time, may be accessed by the front panel using either a rotary dial or a keypad. All measurement and source values along with the elapsed time may also be obtained over the IEEE-488 bus.

The internal memory is organized to obtain and present measurement results in a versatile and easy to understand manner. All source values and corresponding measurement values are stored in sequence and share a common index.

FIGURE 1: Internal Memory

Memory Dial

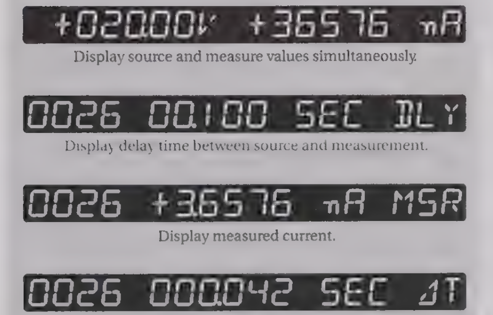
← SELECT →

STEP	SOURCE	DELAY	MEASURE	TIME (ΔT)
0001	+1.0000 V	00.100 s	+1.0921 nA	000.002 s
0002	+02.000 V	00.100 s	+1.1526 nA	000.003 s
0003	+03.000 V	00.100 s	+1.2234 nA	000.005 s
0004	+04.000 V	00.100 s	+2.3725 nA	000.006 s
0005	+05.000 V	00.100 s	+2.7713 nA	000.008 s
-	-	-	-	-
0028	+028.00 V	00.100 s	+3.6576 nA	000.042 s
-	-	-	-	-
1000	+1000.0 V	00.100 s	+8.5763 nA	001.503 s

Data Display

The contents of the internal memory may be accessed via the IEEE-488 bus or displayed in several formats using the front panel controls. Source and measure values may be displayed simultaneously, or with the index value. Delay and elapsed time may also be displayed with the index. The choice between display modes is conveniently made using the Select keys. The delay time between source and measurement may be independently set from 0 to 65,000ms from the front panel or the IEEE-488 interface.

FIGURE 2: Data Displays



Display source and measure values simultaneously.

Display delay time between source and measurement.

Display measured current.

Display time (ΔT).

Selectable Sweeps of Voltage and Current

The 236, 237 and 238 may be programmed to perform source-measurements as a function of a stepped voltage or current. Voltage and current may be swept linearly, logarithmically, or pulsed. The START, STOP, STEP method of setting sweep parameters allows operators to become proficient at using the instrument very quickly. Sweep parameters may be appended (APPEND key) to obtain more complex test sequences.

Creating custom sweeps of voltage or current is facilitated by the use of three waveform operations: CREATE, APPEND, and MODIFY. These allow the user to select waveform parameters, combine multiple waveforms, and select and change any points in a waveform previously created or appended.

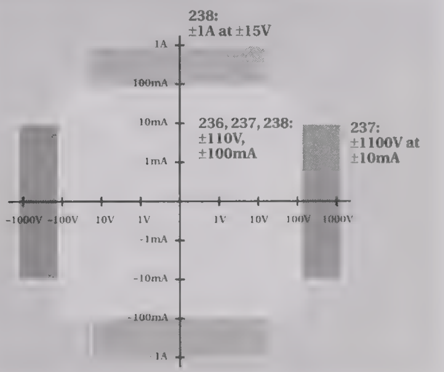
Fully-Guarded Four-Terminal Measurements

The 236, 237 and 238 outputs and inputs are fully guarded, and the units are configured to allow four-terminal measurements. Two-terminal measurements are also available for more standard test procedures. These outputs may be floated up to ±200V from ground.

Source Capability

The 236, 237 and 238 deliver full output current at maximum voltage to allow for optimum characterization of high-power devices. The 236 delivers up to 100mA at 110V, the 237 delivers 10mA at 1100V, and the 238 delivers 1A at 15V.

FIGURE 3: SMU Source Capability



Suppression

Pushbutton suppression lets you make relative measurements with respect to a baseline, or cancel background signals. Suppression for a particular measurement may be any value within the specified operating range of the instrument.

Fast, efficient programming makes these Source-Measure Units the ideal systems for a wide range of testing procedures in the most comprehensive systems.

ACCESSORIES AVAILABLE

CABLES

236-ILC-3	Interlock Cable, 3m (10 ft.)
7078-TRX-3	3-Slot Low Noise Triax Cable, 0.9m (3 ft.)
7078-TRX-10	3-Slot Low Noise Triax Cable, 3m (10 ft.)
7078-TRX-20	3-Slot Low Noise Triax Cable, 6m (20 ft.)

RACKS & RACK MOUNT KITS

1938	Fixed Rack Mount Kit
1939	Slide Rack Mount Kit
8000-10	Equipment Cabinet, 10 in. high
8000-14	Equipment Cabinet, 14 in. high

SOFTWARE

251	I-V Test Software (p.77)

SWITCHING (p. 109)

707	Switching Matrix
7072	Semiconductor Matrix Card
7072-HV	High Voltage Semiconductor Matrix Card
7153	High Voltage Low Current Matrix Card

TEST FIXTURES

8006	Component Test Fixture
8007	Semiconductor Test Fixture

OTHER

213	Quad Voltage Source (p. 144)
2361	Trigger Controller Unit (p. 82)

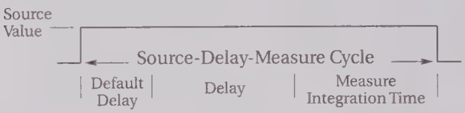
See page 163 for descriptions of all accessories.

Source-Measure Units

SOURCE-MEASURE UNIT: Sources voltage while measuring current, or sources current while measuring voltage.

FUNCTION: Can be used as DC source or meter, sweep source, or full source-measure unit.

SOURCE-DELAY-MEASURE CYCLE:



Default Delay: Fixed delay for instrument settling.

User Delay: Additional delay for device under test or system capacitance.

MEASURE:

INTEGRATION TIME		
Fast	416 µs	4 digit resolution
Medium	4 ms	5 digit resolution
Line Cycle	16.67 ms (60 Hz) 20.00 ms (50 Hz)	5 digit resolution

Elapsed Time: Measures and stores time from sweep trigger to measurement complete for each step of sweep.

RANGING:

Source: Auto-ranging through keypad entry; fixed range selection using rotary dial and SELECT keys (DC function). Fully programmable in SWEEP function.

Measure: Auto or fixed range. Fixed range selection made by choice of COMPLIANCE value.

FILTER: Takes n measurements, calculates and outputs average (n = 2, 4, 8, 16, or 32, selectable).

SUPPRESS: Subtracts displayed measurement from subsequent readings.

MENU: DC Measurement Delay, Default Delay On/Off, Local/Remote Sense, 50/60Hz, IEEE Address, Self Tests.

DATA ENTRY: Numeric keypad or detented rotary dial.

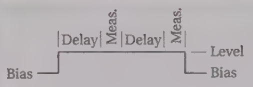
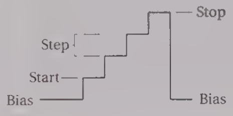
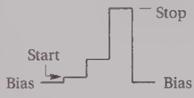
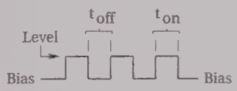
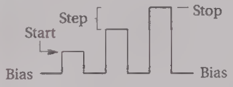
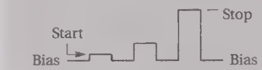
TRIGGER:

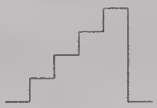
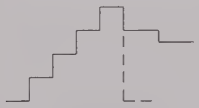
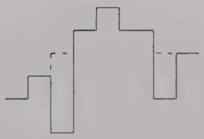
Input and Output: Set for any phase of SOURCE-DELAY-MEASURE sequence or trigger output at end of sweep.

Origin: Internal, External (including front panel MANUAL TRIGGER button), IEEE-488 bus (TALK, GET, "X").

MEMORY: Stores one full sweep (up to 1000 points) of source, delay, and measure values, elapsed times, and sweep parameters. Lithium battery backup.

INTERLOCK: Use with test fixture or external switch. Normally closed; open puts instrument in standby.

SWEEP WAVEFORMS	DESCRIPTION
 Fixed Level	LEVEL, COUNT (number of DELAY-MEASURE cycles), DELAY, BIAS
 Linear Stair	START, STOP, STEP, DELAY, BIAS
 Logarithmic Stair	START, STOP, POINTS/DECADE (5, 10, 25, or 50), DELAY, BIAS
 Pulse	LEVEL, COUNT, T_{ON}, T_{OFF}, BIAS
 Linear Stair Pulse	START, STOP, STEP, T_{ON}, T_{OFF}, BIAS
 Logarithmic Stair Pulse	START, STOP, POINTS/DECADE (5, 10, 25, or 50), T_{ON}, T_{OFF}, BIAS

WAVEFORM OPERATORS	DESCRIPTION
 Create	Allows selection of waveform parameters. Generates all source values.
 Append	Combines multiple waveforms and adds new points to those already in memory.
 Modify	Select and change any points in a previously created (or appended) waveform.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and setups are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, and Terminator.

IEEE-488 address is set from front panel menu.

EXECUTION SPEED

MINIMUM SOURCE-DELAY-MEASURE CYCLE TIME: 1ms.

RESPONSE TO IEEE-488 COMMAND (as a source): 25ms.

MEASUREMENT RATE: 1ms per point into internal buffer.

CONTINUOUS MEASUREMENT SPEED (source DC value over IEEE-488 bus): 110 readings per second.

TRIGGER LATENCY TIME: <2ms.

GENERAL

LOAD CAPACITANCE: Stable into 20,000pF typical.

REMOTE SENSE: Corrects for up to 2V drop in each output lead. Maximum 1kΩ per sense lead for rated accuracy. Residual output resistance (as a voltage source) is 0.5Ω.

GUARD: Output Resistance: ≤12kΩ.
Maximum Output Current: ±2mA.
Offset Relative to Output HI: ±2mV max.

ISOLATION (Output LO to chassis): Typically $>10^{10}\Omega$ in parallel with 500pF (650pF on Model 238).

MAXIMUM COMMON MODE VOLTAGE: 200V.

CONNECTORS: Outputs: 3-lug triax.
Trigger Input/Output: BNC.
Interlock: 3-pin miniature DIN.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

ENVIRONMENT:
Operating: 0°–50°C, 70% relative humidity up to 35°C. Linearly derate 3% RH/°C, 35°–50°C.
Storage: –25° to 65°C.

WARM-UP: One hour to rated accuracy.

COOLING: Internal fan forced air cooling.

POWER: 105–125 or 210–250V AC (external switch selectable), 90– 110V and 180–220V version available. 100VA max. (120VA max. on Model 238).

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in. × 17⅛ in. × 17⅝ in.). Net weight 9kg (19.75 lbs.).

VOLTAGE	SOURCE[1]			MEASURE[1]		
	RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year) 18°–28°C	RESOLUTION 4 Digit	5 Digit	ACCURACY (1 Year) 18°–28°C
236, 237	±1.1000 V[2]	100 µV	±(0.033%+650 µV + $[I_O/I_{FS}]$ × 450µV)	100 µV	10 µV	±(0.028% + 300µV + $[I_O/I_{FS}]$ × 450µV)
	±11.000 V	1 mV	±(0.033% + 2.4mV)	1 mV	100 µV	±(0.025%+ 1mV)
	±110.00 V	10 mV	±(0.033% + 24mV)	10 mV	1 mV	±(0.025%+ 10mV)
237 Only	±1100.0 V	100 mV	±(0.04 % + 240mV)	100 mV	10 mV	±(0.035%+100mV)
238 Only	±1.5000 V	100 µV	±(0.033% +800 µV + $[I_O/I_{FS}]$ × 600µV)[3]	100 µV	10 µV	±(0.028% + 450µV + $[I_O/I_{FS}]$ × 600µV)
	±15.000 V	1 mV	±(0.033% + 2.7mV)	1 mV	100 µV	±(0.025%+ 1mV)
	±110.00 V	10 mV	±(0.033% + 24mV)	10 mV	1 mV	±(0.025%+ 10mV)

I_O = Output current; I_{FS} = Full scale on selected current range

[1] Specifications apply for 5-digit resolution. For 4-digit resolution add 100ppm of range.

[2] Assumes remote sense for I > 100µA.

[3] On the 1A range use $[I_O/I_{FS}]$ × 250µV.

COMPLIANCE: Bipolar current limit set with single value.
Maximum: ±100mA (except ±10mA on 1100V range in Model 237 and ±1A on 15V range in Model 238).
Minimum: ±1% of range, except 0.5% of 1.1V range.
Accuracy, Step Size: Same as current source.

NOISE (p-p):

Range	0.1–10Hz	[illegible]
110 V – 1100 V	< 3ppm of range	40 mV
11 V (15 V on 238)	< 3ppm of range	15 mV
1.1 V (1.5V on 238)	<10ppm of range	15 mV

WIDEBAND NOISE: 0.1 to 20MHz, 8mV p-p typical.

OVERSHOOT: <0.01% (110V step, 10mA range).

SETTLING TIME: <500µs to 0.01% (110V step, 10mA range).

NMRR: >60dB at 50 or 60Hz (LINE CYCLE integration time selected).

CMRR: >120dB at DC, 50 or 60Hz (LINE CYCLE integration time selected).

INPUT IMPEDANCE (as a voltmeter): $>10^{14}\Omega$ paralleled by <20pF.

CURRENT	SOURCE[1]			MEASURE[1]		
	RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year) 18°–28°C	RESOLUTION 4 Digit	5 Digit	ACCURACY (1 Year) 18°–28°C
All	±1.0000 nA	100 fA	±(0.3 %+ 450 fA)	100 fA	10 fA	±(0.3 %+ 100 fA)[2]
	±10.000 nA	1 pA	±(0.3 %+ 2 pA)	1 pA	100 fA	±(0.3 %+ 1 pA)
	±100.00 nA	10 pA	±(0.21%+ 20 pA)	10 pA	1 pA	±(0.21 %+ 6 pA)
	±1.0000 µA	100 pA	±(0.05%+ 200 pA)	100 pA	10 pA	±(0.04 %+ 60 pA)
	±10.000 µA	1 nA	±(0.05%+ 2 nA)	1 nA	100 pA	±(0.035%+ 700 pA)
	±100.00 µA	10 nA	±(0.05%+ 20 nA)	10 nA	1 nA	±(0.035%+ 6 nA)
	±1.0000 mA	100 nA	±(0.05%+ 200 nA)	100 nA	10 nA	±(0.035%+ 60 nA)
	±10.000 mA	1 µA	±(0.05%+ 2 µA)	1 µA	100 nA	±(0.038%+ 600 nA)
	±100.00 mA	10 µA	±(0.1 %+ 20 µA)	10 µA	1 µA	±(0.1 %+ 6 µA)
238 Only	±1.0000 A	100 µA	±(0.12%+ 700 nA)	100 µA	10 µA	±(0.12 %+ 300 µA)

[1] Specifications apply for 5-digit resolution. For 4-digit resolution, all offset terms are 200ppm of range.

[2] Offset specification applies for 23°C ± 1°C with suppression. Temperature coefficient 50fA/°C.

COMPLIANCE: Bipolar voltage limit set with single value.
Maximum: ±1100V (except ±110V in Model 238 and on 100mA range in Model 237).
Minimum: ±0.1% of selected current range.
Accuracy, Step Size: Same as voltage source.

NOISE (p-p of range): 0.1–10Hz: <3ppm (<20ppm on 1nA and 10nA ranges and on 1A range in Model 238).

OVERSHOOT: <0.01% typical (10mA step, R_L = 10kΩ).

SETTLING TIME: <500µs to 0.01% (10mA step, R_L = 10kΩ).

OUTPUT R, C: $>10^{14}\Omega$ paralleled by <20pF (on 1nA range).

Model 82 Simultaneous C-V Systems

- **Measure doping profile and D_{IT} for MOS device characterization.**
- **High frequency and quasistatic C-V curves are acquired *simultaneously* to avoid errors due to voltage stress.**
- **Menu-driven software for measurement and analysis runs on DOS or HP computers.**
- **Built-in diagnostics and correction for common error sources for confidence in your results.**

ORDERING INFORMATION

Model 82
Simultaneous C-V System for HP Computers

Model 82-DOS
Simultaneous C-V System for AT-Compatible DOS Computers

Model 82-PS/2
Simultaneous C-V System for PS/2-Compatible DOS Computers

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

CABLES

4801	Low Noise BNC Input Cable, 1.2m (4 ft.)
4803	Low Noise Cable Kit
7007-1	Shielded IEEE-488 Digital Cable, 1m (3.3 ft.)
7007-2	Shielded IEEE-488 Digital Cable, 2m (6.6 ft.)
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5	BNC Interconnect Cable, 1.5m (5 ft.)
7051-10	BNC Interconnect Cable, 3m (10 ft.)

CALIBRATION

5955	Calibration Capacitor Set

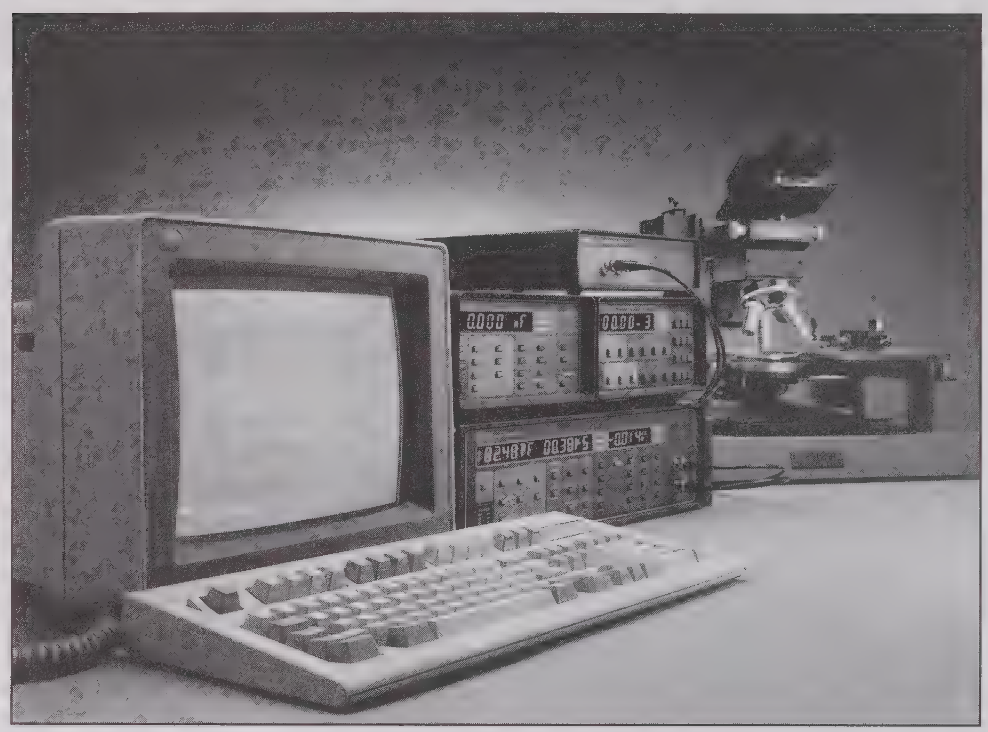
SOFTWARE

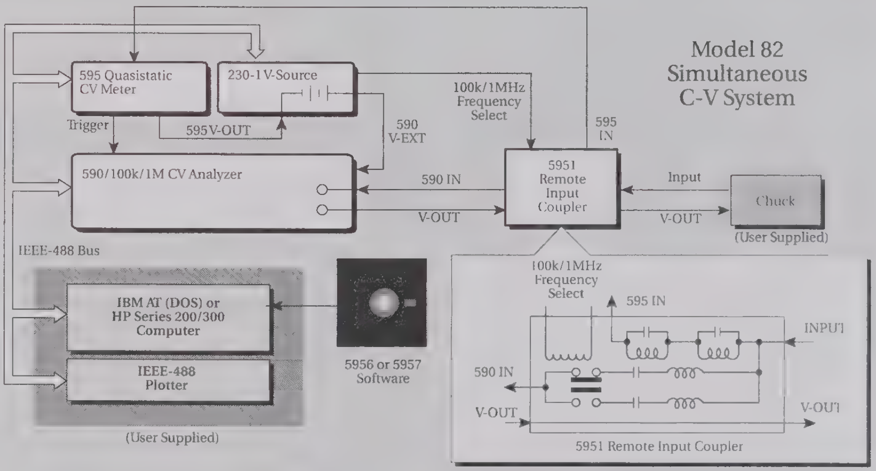
5958	C-V Utilities Software

RACK MOUNT KITS

1019A-2	Dual Fixed Rack Mount Kit (for 230-1 and 595)
2288	Fixed Rack Mount Kit (for 590)
8000-10	Equipment Cabinet

See page 163 for descriptions of all accessories.


0.000 nF
0.000-3
82481F 00.38F5 -001.4F


Model 82 Simultaneous C-V System
595 Quasistatic CV Meter
230-1 V-Source
Trigger
595 V-OUT
590 V-EXT
100k/1MHz Frequency Select
595 IN
590/100k/1M CV Analyzer
590 IN
V-OUT
5951 Remote Input Coupler
Input
V-OUT
Chuck
(User Supplied)
IEEE-488 Bus
IBM AT (DOS) or HP Series 200/300 Computer
IEEE-488 Plotter
(User Supplied)
5956 or 5957 Software
100k/1MHz Frequency Select
595 IN
INPUT
590 IN
V-OUT
V-OUT
5951 Remote Input Coupler

Simultaneous C-V Measurements

Making precise measurements of interface state densities and doping profiles (including effects of interface states) used to take a lot of time, and usually produced questionable results. These measurements require C-V curves which are typically developed by one of two methods:

1. Comparing a measured C-V curve to calculated theoretical data. (Assumptions necessary in the calculations introduce errors.)
2. Measuring high frequency and quasistatic C-V curves sequentially. However, voltage stress from sweeping the voltage twice can cause misalignment of the C-V curves. This leads to inaccurate results.

The errors introduced by these two methods can be greatly reduced by measuring both quasistatic and high frequency data in one voltage sweep*.

---

*Nicollian, E. H. and Brews, J. R., MOS Physics and Technology, Wiley, New York (1982).

Simultaneous C-V Systems

The Model 82 Simultaneous C-V System is the first product to make simultaneous quasistatic and high frequency C-V measurements, reducing the measurement time and inaccuracies of older techniques without changing connections to the device under test.

Choose Your System

Model 82 System Software is available for either your IBM AT (or 100% compatible), PS/2, HP controller, or HP BASIC Language processor card in a DOS computer. The Model 5958 C-V Software Utilities are available for IBM AT or PS/2 computers (see **Table 1**).

Easy to Use

The Model 82 menu-driven software steps you through the process required to do fast and accurate C-V analysis. It corrects for system leakages and cabling effects, finds oxide capacitance and equilibrium sweep rate, makes *simultaneous* high frequency and quasistatic C-V measurements, analyzes the data, and plots the output graphs. All of the calculations and graphs commonly used for C-V analysis are included, such as D_{IT}, doping profile, and Q/t (see **Table 2**). All DOS data files are stored in ASCII format so they can be easily accessed by most of your favorite software.

Both the HP (HP BASIC) and the DOS (QuickBASIC) software packages are provided with source code to permit program modification to suit your particular needs.

Fast

By measuring both the high frequency and quasistatic capacitance with one voltage sweep, measurement time is greatly reduced. The Model 82 enables rapid determination of the delay time required to assure device equilibrium.

Accurate

The Model 82 improves accuracy through:

- Simultaneous measurements, eliminating voltage stress errors caused by sequential voltage sweeps.
- Automatic correction of leakages and cabling errors.
- Superior quasistatic measurements using Keithley's "Feedback Charge" technique (see Model 595 in this section).

Fits Your Needs

The Model 82 can be ordered in stages. With either the 590 or 595 C-V meter plus the software (see **Table 2**), you can start making measurements immediately. As budget or measurement requirements change, you can easily upgrade to a complete Model 82.

TABLE 1: C-V Product Selector Guide

Product:	82	82-DOS	82-PS/2	C-V Utilities
Software Model Provided:	5956	5957-DOS	5957-PS/2	5958
Programming Language:	HP BASIC 4.0	QuickBASIC	QuickBASIC	QuickBASIC
Computer:	HP 200/300 or HP BASIC Lang. Proc. Card 1 MB memory	AT-compatible DOS 3.2 or greater 640kB memory	PS/2 DOS 3.2 or greater 640kB memory	AT or PS2 DOS 3.2 or greater 640kB memory

TABLE 2: C-V MEASUREMENT CAPABILITIES

Product:	82, 82-DOS, 82-PS/2			5958 C-V Utilities	
Program Name:	M595CV	M590CV	Pkg82CV	BTS	Zerbst
INSTRUMENT CONTROL					
Quasistatic CV[1]	•		•		
High Frequency CV[2]		•	•	•	•
Simultaneous CV[3]			•		
Temperature Control[4]				•	
GPIB Device Control[5]				•	•
Automatic Test Sequence (up to 5 tests)				•	•
GRAPHICAL ANALYSIS					
Measured Graphs:					
Quasistatic Capacitance vs. Gate Voltage	•		•		
Q/t Current vs. Gate Voltage	•		•		
Quasistatic C and Q/t Current vs. Delay Time	•		•		
High Frequency Capacitance vs. Gate Voltage		•	•	•	•
Conductance vs. Gate Voltage		•	•	•	•
Pulsed High Frequency C vs. Gate Voltage				•	•
High Frequency Capacitance vs. time (C-t)					•
Simultaneous Capacitance vs. Gate Voltage			•		
Calculated Graphs:					
Interface Trap Density vs. Trap Energy			•		
Doping vs. Depletion Depth		•	•	•	•
Depletion Depth vs. Gate Voltage		•	•	•	•
High Frequency $1/C^2$ vs. Gate Voltage		•	•		
Band Bending vs. Gate Voltage			•		
High Frequency C vs. Band Bending			•		
Quasistatic C vs. Band Bending			•		
Zerbst Plot					•
CALCULATED PARAMETERS					
Flatband C and V		•	•	•	•
Threshold Voltage		•	•	•	•
Bulk Doping		•	•	•	•
Average Doping				•	•
Effective Oxide Charge Density, Q_{EFF}		•	•		•
Mobile Ion Charge Density, Q_{MI} and N_{MI}				•	
Effective Surface Charge Density, Q_{SS} and N_{SS}				•	
Metal-Semiconductor Work Function		•	•	•	•
Oxide Thickness and Gate Area	•	•	•	•	•
Debye Length		•	•		
Bulk Potential		•	•		
"Best Depth"		•	•	•	•
Minority Carrier Lifetime					•
Surface Generation Velocity					•

[1] Using Model 595 Quasistatic C-V Meter.
[2] Using Model 590 C-V Analyzer.
[3] Using Models 595, 590, 5951, and 230-1.
[4] Using Temptronic Hot Chuck (user supplied).
[5] To control devices such as a switch matrix (705, 706, 707) or GPIB Prober.

Model 82 Simultaneous C-V Systems

HIGH FREQUENCY CAPACITANCE

100kHz

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
200 pF	10 fF	0.7 + 0.05	0.03	180 fF
2 nF	100 fF	0.9 + 0.5	0.08	1800 fF

1MHz

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
200 pF	10 fF	0.9 + 0.05	0.03	200 fF
2 nF	100 fF	1.4 + 0.5	0.14	400 fF

SHUNT CAPACITANCE LOADING EFFECT: 0.1% of reading additional error per 100pF load with equal shunt load on input and output.

TEST VOLTAGE: 15mV rms ± 10%. **TEST FREQUENCY TOLERANCE:** ±0.1%.

QUASISTATIC CAPACITANCE

[illegible]	[illegible]	[illegible]	[illegible]
200 pF	10 fF	1.0 + 0.1	(0.12% rdg + 0.13 pF) × (100 mV/STEP V) + 0.01 pF
2 nF	100 fF	0.8 + 0.2	(0.09% rdg + 0.13 pF) × (100 mV/STEP V) + 0.1 pF

TEMPERATURE COEFFICIENT (0°–18° & 28°–40°C): ±(0.02% rdg + 0.1 pF)/°C.

[illegible]

ACCURACY (1 Year, 18°–28°C): ±(0.05% rdg + 50mV).

RESOLUTION: 10mV.

TEMPERATURE COEFFICIENT (0°–18° & 28°–40°C): ±(0.005% + 1mV)/°C.

[illegible]

[illegible]	[illegible]	[illegible]
≤ 20 V	150 µV	10 mV
> 20 V to 120 V	250 µV	100 mV

[1] Typically 3 mV up to 75 MHz.

MAXIMUM SWEEP SPAN, $|V_{START} - V_{STOP}|$: 40V.

MAXIMUM OUTPUT CURRENT: ±2mA (–0%, +20%).

SWEEP STEP VOLTAGE SELECTIONS: 10mV, 20mV, 50mV, 100mV.

DC OUTPUT RESISTANCE: <10Ω.

*NOTES

Specifications are based on parallel RC model and Quality Factor ≥20.

Assumes proper cable correction and open circuit suppression.

Quasistatic capacitance accuracy is exclusive of noise, for STEP V ≥ 0.05V and DELAY TIME ≤ 1 second. For other parameters, derate by (5mV/STEP V) × (DELAY TIME/1 second) in pF at 23°C. Double the derating for every 10°C rise in ambient temperature above 23°C.

Typical allowable non-equilibrium current plus leakage current: <20pA on 200pF range; <200pA on 2nF range during capacitance measurements.

GENERAL

READING RATES: 4½ readings per second to one reading every 400 seconds.

DATA BUFFER: 1000 points maximum.

GRAPHICAL OUTPUTS: Computer display or digital plotter supporting HPGL with IEEE-488 interface; also "screen copy" to compatible printer.

DIGITAL I/O: Consists of one output, four inputs, +5V (series limited with 33Ω), and COMMON referenced to IEEE-488 COMMON. Output will drive one TTL load. Inputs represent one TTL load.

MAXIMUM INPUT: 30V peak, DC to 60Hz sine wave.

MAXIMUM COMMON MODE VOLTAGE: 30V maximum, DC to 60Hz sine wave.

OPERATING ENVIRONMENT: 0° to 40°C, 70% non-condensing RH up to 35°C.

STORAGE ENVIRONMENT: –25° to +65°C.

WARM-UP: 2 hours to rated accuracy.

SYSTEM CONFIGURATION: Models 230-1, 590, 595, and 5951 connected as shown in manual.

MINIMUM DOS COMPUTER CONFIGURATION:
- IBM AT, PS/2, or 100% compatible with:
  - DOS 3.2 or greater
  - 640k of memory
  - Hard disk drive
  - CGA, EGA, VGA, or Hercules Graphics adapter.
- Compatible with IEEE-488 cards:
  - National Instruments PC-II, PC-IIA, PC-III
  - IBM GPIB adapter
  - Keithley PC-488-CEC
  - Keithley 4-488-CEC-0M
  - Keithley 4-488-CEC-1M
  - Capital Equipment 01000-00300
  - IOtech GP488, GP488A
  - For PS/2 operation, IOtech Personal 488/2 is required.

MINIMUM HP COMPUTER CONFIGURATION:
HP Series 200 or 300 with BASIC 4.0, 1MB of memory, or HP-BASIC card in AT-compatible computer.

MODEL 82, 82-DOS COMPONENTS:

230-1	Programmable Voltage Source
595	Quasistatic C-V Meter
590	100k/1M C-V Analyzer
5909	Calibration Sources
5956	Model 82 C-V Software and Manual (for HP computers)
5957	Model 82-DOS C-V Software and Manual (for DOS computers)
5951	Remote Input Coupler—Includes Models:
4801	Low Noise BNC Cable, 1.2m (4 ft.) (5 supplied)
7007-1	Shielded IEEE-488 Cable, 1m (3.3 ft.) (2 supplied)
7007-2	Shielded IEEE-488 Cable, 2m (6.6 ft.) (1 supplied)
7051-2	RG-58C BNC to BNC Cable, 0.6m (2 ft.) (3 supplied)

For additional information about C-V or a free copy of the Model 82 Demonstration Guide and software, call our Applications Department at **1-800-552-1115 (U.S. only).**

C-V Utilities Software

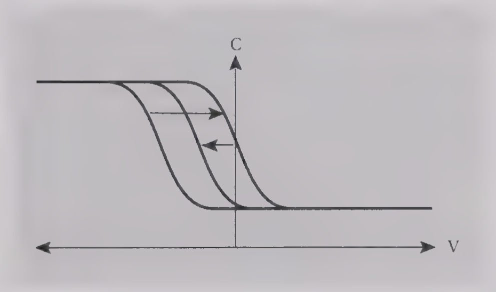
The Model 5958 C-V Utilities Software includes menu-driven programs for conducting standard Bias Temperature Stress (BTS) and C-t Zerbst tests. The utilities operate on PS/2 or AT-compatible computers under DOS to acquire, display, and print C-V and C-t curves and derived characteristics. See C-V Measurement Capabilities, **Table 2** on page 89 for a full list of the analysis performed by the 5958.

Applications

Bias Temperature Stress (BTS) Test monitoring of mobile ionic charge density is among the most common process monitoring C-V applications. Control of mobile ionic charge is crucial to the production of quality semiconductor devices. MOS Threshold Voltage predictability and stability can be greatly improved by controlling mobile ions such as sodium and potassium in the oxide or other insulator.

Minority Carrier Lifetime is measured using Zerbst analysis of capacitance versus time (C-t) data. This key parameter is related to device performance such as dynamic memory cell refresh time, junction leakage, and CCD dark current.

Bias Temperature Stress Testing

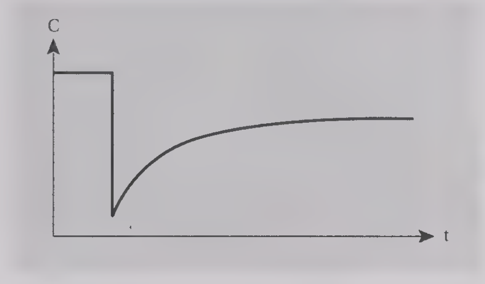


BTS tests are performed by interleaving C-V curve acquisition from a Metal-Insulator-Semiconductor (MIS) capacitor with positive and negative gate voltage stress cycles at high temperature (200°-300°C). The voltage stress at high temperature causes movement of any ionic contaminants present in the MIS insulator. The mobile ion concentration is determined by measuring flatband voltage shift using the C-V curves. Ion movement is distinguished from annealing of surface or oxide charge by comparing both positive and negative voltage stresses.

When performing BTS tests, the Model 590 acquires stair or pulsed C-V curves at either 100kHz or 1MHz to measure the device flatband voltage. An optional Model 230-1 Voltage Source may be used with the system to extend its voltage range from ±20V to ±100V. The Temptronic hot chuck (user supplied) heats the device under test to as high as 300°C while positive and negative stress voltage are applied during Stress cycles.

Up to five devices may be tested automatically without operator intervention using a test sequence. User-defined GPIB command strings are alternated with BTS tests in the sequence for control of any GPIB device, such as a switch matrix or semi-automatic prober, to select from various test devices. Test sequence automation results in increased repeatability and efficiency in testing, higher productivity and improved yield.

Zerbst Plots from C-t Data



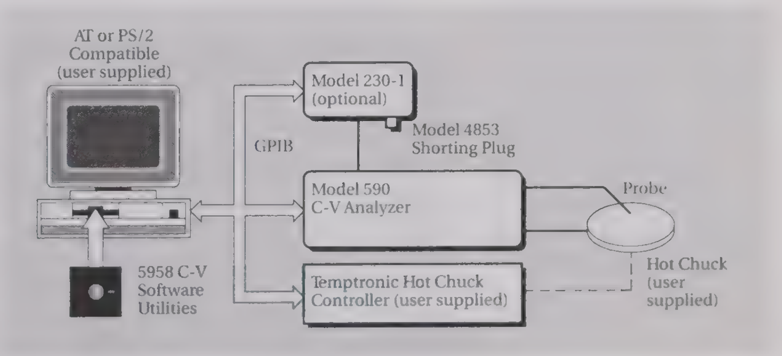
The Model 590 is also utilized by the Zerbst/C-t utility program to measure C-t data as fast as 1ms per sample. Convenient display of Zerbst analysis graphically confirms proper time interval selection and linear fit to the data. Minority carrier lifetime and surface generation velocity are automatically calculated from the Zerbst plot.

C-t data is directly acquired by the Model 590 C-V Analyzer for optimum accuracy, entered into its data buffer then transferred to the computer.

Software Compatibility with Model 82 Simultaneous C-V System

The user interface and data files for the utilities are compatible with the software of Model 82-DOS and Model 82-PS/2 Simultaneous C-V Systems. Thus 5958 data files may be loaded by the Model 82 for complete analysis and for comparison to simultaneous C-V data.

QuickBASIC source code is provided to permit program modification, such as to customize hot chuck control, data acquisition, analysis, or reporting.


AT or PS/2 Compatible (user supplied)
Model 230-1 (optional)
GPIB
Model 4853 Shorting Plug
Model 590 C-V Analyzer
Probe
5958 C-V Software Utilities
Temptronic Hot Chuck Controller (user supplied)
Hot Chuck (user supplied)

- **Detect mobile ion contamination using BTS tests.**
- **Measure minority carrier lifetime using C-t tests.**
- **Menu-driven software for measurement and analysis runs on AT and PS/2 computers.**
- **Fully compatible with Model 82-DOS and Model 82-PS/2 Simultaneous C-V Systems for D_{IT} characterization.**

[illegible]

5958
Bias Temperature Stress and Zerbst Software Utilities for AT- and PS/2-Compatible DOS Computers

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

5958 C-V Utilities Software

OVERVIEW

SOFTWARE UTILITIES: Bias Temperature Stress (BTS) Program C-t/Zerbst Program.

INSTRUMENTS CONTROLLED: Model 590 C-V Analyzer (required)

Model 230-1 Voltage Source (optional)

Temptronic Hot Chuck (user supplied, for BTS only)

CAPACITANCE MEASUREMENT: All 590 C and G measurement ranges

100k or 1M test signal frequency

Series or parallel model

Stair and pulsed stair waveforms

DATA DISPLAY: Graphic or list display of acquired data. Tabular display of calculated parameters.

FILES: Test File: Contains all setup parameters of Test Sequence, C-V Measurement, and Stress Cycle.

Data File: Each contains one C-V or C-t curve.

Configuration File: Specifies Graphics Card, Printer, and Plotter.

C-t / ZERBST PROGRAM

C-t MEASUREMENT: C-t measurement plus basic C-V for measurement of oxide thickness or gate area and semiconductor doping. Programmable C-t voltage step and sampling parameters.

ANALYSIS: Minority carrier lifetime, surface generation velocity, oxide thickness, gate area, flatband voltage and capacitance, semiconductor doping, threshold voltage, metal-semiconductor work function.

MATERIALS PROVIDED:

Instruction manual

Diskettes containing installation, programs, source code, and sample data.

BTS PROGRAM

C-V MEASUREMENT: Each BTS test consists of three C-V Curves: Initial, After + Stress, and After - Stress.

STRESS CYCLE: Programmable stress voltage, temperature, and time.

ANALYSIS: Mobile ion density, surface charge density, oxide thickness and gate area, flatband voltage and capacitance, semiconductor doping, threshold voltage, metal-semiconductor work function.

TEST SEQUENCES: Up to 5 BTS tests per sequence. Stores acquired data automatically in designated data files. Outputs user-defined GPIB control strings before and after test sequence and prior to each BTS test in the sequence.

GPIB CONTROL: Provides for control of any GPIB device, such as a switch matrix, to configure device connections. Each GPIB control string consists of device address plus up to 64 ASCII characters.

SYSTEM REQUIREMENTS

MINIMUM COMPUTER CONFIGURATION: IBM AT, PS/2, or 100% compatible, 640kB RAM, hard disk drive, 360kB 5¼-inch or 720kB 3½-inch floppy drive.

OPERATING SYSTEM: MS-DOS or PC-DOS 3.2 (minimum).

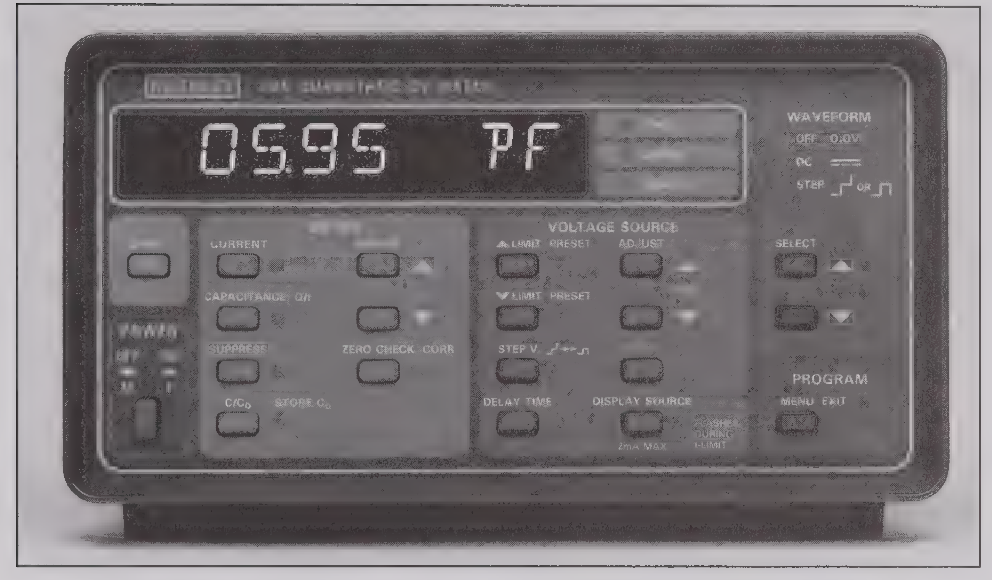
GRAPHICS ADAPTER: CGA, EGA, VGA (EGA mode), or Hercules Graphics Adapter.

IEEE-488 (GPIB) INTERFACE CARDS SUPPORTED:
National Instruments PC-II, PC-IIA, PC-III
Keithley PC-488-CEC, 4-488-CEC-0M, 4-488-CEC-1M
IBM GPIB Adapter
Capital Equipment 01000-00300
IOtech GP488, GP488A

IOtech Personal 488/2 or National Instruments MC-GPIB is required for PS/2 operation.

Quasistatic C-V Meter

595



0595 PF
WAVEFORM
OFF 0.0V
DC
STEP
CURRENT
CAPACITANCE
SUPPRESS
ZERO CHECK CORR
C/C₀
STORE C₀
POWER
VOLTAGE SOURCE
LIMIT PRESET
ADJUST
STEP V
DELAY TIME
DISPLAY SOURCE
2mA MAX
SELECT
PROGRAM
MENU EXIT

- Measures quasistatic capacitance (10fF–20nF) and DC current (1fA–200μA)
- Correction of capacitance readings for background leakage currents
- Rapid assurance of device equilibrium
- Superior signal-to-noise performance, even with the slow voltage sweeps required by today's state-of-the-art devices.

IEEE-488

The Keithley 595 Quasistatic C-V Meter measures quasistatic capacitance versus voltage (C-V) characteristics of MIS semiconductor devices. The new C-V measurement technique used by the 595 provides diagnostics and correction for common sources of errors to increase confidence in test results.

Its current function serves as a sensitive picoammeter, directly measuring DC currents to 1fA. The built-in ±20V voltage source with DC, staircase, and squarewave waveforms permits both current and quasistatic capacitance measurements to be made either at a single device bias or as a function of voltage. This measurement flexibility makes the 595 appropriate for characterization of many semiconductor materials and components.

Quasistatic C-V measurements in the 595 are made using the "feedback charge" technique. Use of this technique makes it easy to measure quasistatic C-V characteristics of devices that would be unsuitable for testing with the traditional ramp method and static or Q-V methods.

Feedback charge brings to the 595:

- The ability to detect and correct for device or fixture leakage currents
- Rapid and quantitative indication of device equilibrium
- Superior signal-to-noise performance—even with the slow voltage sweeps required by today's state-of-the-art devices.

Applications

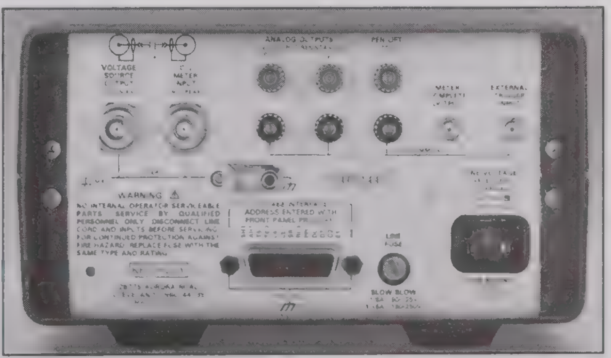
Quasistatic C-V measurements are commonly applied to characterize Metal-Insulator-Semiconductor (MIS) devices. They are used in the measurement of interface trap density and doping profiles corrected for the presence of interface traps. Quasistatic C-V is also used to measure mobile ion density by the triangular voltage-sweep method.

Measurements made with the 595 agree with quasistatic C-V results obtained using the ramp technique on silicon MOS devices. But the unique leakage correction capability of the feedback charge technique permits measurement of less-ideal MIS devices such as those based upon silicon carbide, GaAs, HgCdTe, InP, and compound insulators.

The Feedback Charge Method

The feedback charge method is based upon a staircase/squarewave voltage source and a charge measurement circuit, each connected to one terminal of the DUT.

Unlike other charge measurement techniques used for quasistatic C-V measurement, the feedback charge method presents a low impedance at the sensitive charge-measuring node. That reduces the otherwise extreme requirement for high shunt resistance and low shunt capacitance in device connections and further improves measurement integrity.



VOLTAGE SOURCE OUTPUT
METER INPUT
ANALOG OUTPUTS
PEN LIFT
METER COMPLETE
EXTERNAL TRIGGER INPUT
WARNING
NO INTERNAL OPERATOR SERVICEABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD AND INPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING.
ADDRESS ENTERED WITH FRONT PANEL PROGRAM
LINE FUSE
SLOW BLOW

ORDERING INFORMATION

595
Quasistatic C-V Meter with two Model 4801 Low Noise BNC Input Cables

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

CABLES	
4801	Low Noise BNC Input Cable, 1.2m (4 ft.)
4803	Low Noise Cable Kit
7007-1	Shielded IEEE-488 Digital Cable, 1m (3.3 ft.)
7007-2	Shielded IEEE-488 Digital Cable, 2m (6.6 ft.)
CALIBRATION	
5955	Calibration Capacitor Set
SOFTWARE	
5956	Simultaneous C-V Software (for HP computers)
5957	Simultaneous C-V Software (for DOS computers)
RACK MOUNT KITS	
1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

See page 163 for descriptions of all accessories

595 Quasistatic C-V Meter

To automate quasistatic C-V measurements use the 595 in a Model 82, 82-DOS, or 82-PS/2 System.

The voltage source outputs a small voltage step across the DUT, V_{STEP}, as part of either a squarewave or staircase waveform. This voltage step stimulates a displacement charge step in the device capacitance. The charge measurement circuit samples the device charge waveform before and after the stimulated charge step to determine Q_{STEP} and calculates the apparent device capacitance using the relation:

$$C_X = Q_{STEP} / V_{STEP}$$

The slope of the charge versus time waveform after the step, called Q/t, is also measured as an indication of the current flowing through the device at the time of measurement.

In an ideal capacitor, the Q/t current would always be zero since the displacement charge step would be transferred instantaneously at the time of the voltage step and no current would flow in the DUT thereafter in response to the DC voltage bias.

However, in practical devices this is seldom the case and Q/t is used to diagnose device or test error conditions such as:

- Constant leakage current resulting from humidity or electrochemical contamination.
- Parallel leakage resistance due to a leaky MIS device insulator or oxide.
- Non-equilibrium device settling current when the test voltage is swept too quickly.[1]

The 595 can also be used with the squarewave test signal waveform with a sequence of successively longer delay times to identify the test conditions required to achieve device equilibrium in a fraction of the time of other methods. When the measured capacitance saturates to C_{OX} and Q/t stabilizes at the constant leakage current value, the delay time is sufficient for device equilibrium.

Enhancing Measurement Integrity

The 595 has a choice of three non-recursive digital filters which can significantly reduce noise without shifting or distorting the quasistatic C-V curve. They can also be used to reduce measurement noise when measuring steady-state capacitances or currents.

Capacitance readings may be normalized to a stored value of C_O to eliminate the effects of gain errors and ease comparison of results from devices of different sizes.

The effects of current or capacitance offsets may be eliminated using Suppress, which subtracts a designated on-range reading from subsequent readings. Suppress is also useful for measuring relative to a fixed baseline.

FIGURE 1: 595 C vs. V and Q/t vs. V Curves Q/t used to indicate the degree of equilibrium

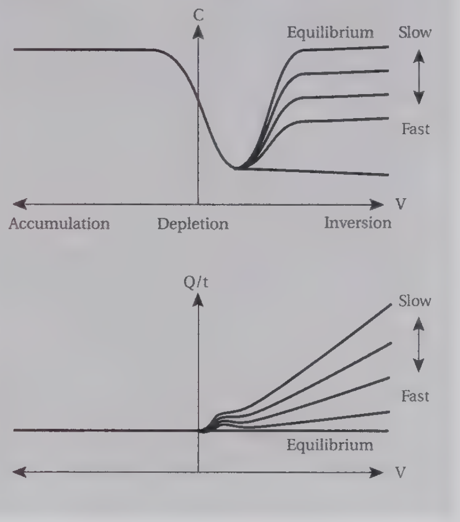
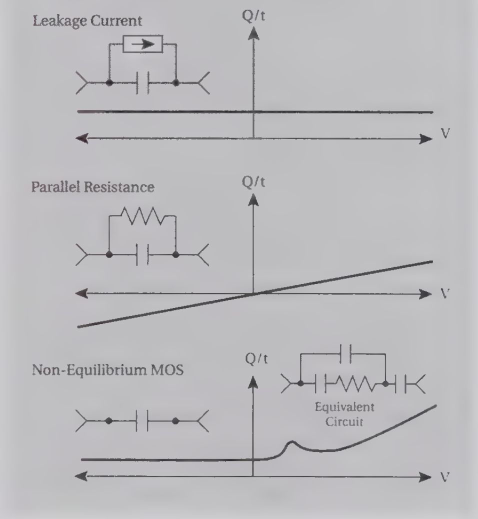


FIGURE 2: Q/t vs. V Curves used to diagnose leakage currents, parallel resistance, or non-equilibrium MOS conditions



Built-In Plotter Driver

You don't need to tie up a computer to make quasistatic C-V, Q/t, or I-V plots with the Model 595. It uses the IEEE-488 bus port to drive an HPGL plotter. No software or computer is needed. The 595 also outputs X-Y graphs with pen control to analog plotters.

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[1] The Model 595 may be used for conventional quasistatic C-V testing in which the test voltage is swept from inversion to accumulation in non-equilibrium. However, results obtained under these conditions should be verified against results of equilibrium tests to ensure that interface trap measurements are not adversely affected.

Quasistatic C-V Meter 595

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

PROGRAMMABLE PARAMETERS: Function, RANGE, ZERO CHECK, CORRect, SUPPRESS, C/C_O, STORE C_O, Voltage Source Parameters, WAVEFORM, Display Parameter, Filter, Trigger, Analog Output ×10, PEN LIFT, Capacitance Correction, Calibration, Self Test, Output Format, SRQ, Status, ASCII Terminator, EOI.

PLOTTER: Controls HP 7470A plotter or equivalent using HPGL via IEEE-488 for real time plotting of C, Q/t, or I vs. V curves. Accessed by selecting Model 595 address 42 or 43. Talks to plotter on address 05. HPGL® commands used are IN, IP, IW, PA, PD, PU, SC, SI, SP.

GENERAL

DISPLAY: 4½-digit numeric LEDs with appropriate decimal point and polarity indication. Signed 2-digit alphanumeric exponent.

UPDATE RATE: In I, one reading each Step Time. In C, one reading each 2× Step Time.

OVERRANGE INDICATION: Display reads OL.

INPUT BIAS CURRENT (all functions): <5fA (5×10^{-15}A) at 23°C after warm-up. Approximately doubles for every 10°C increase in ambient temperature above 23°C.

INPUT VOLTAGE BURDEN: <1mV.

MEASUREMENT SETTLING TIME: Within one reading except 2.5 s (to 1% of step change) on pA ranges.

PROGRAMS: Provide front panel access to Filter, Trigger, Analog Output ×10, Corrected Capacitance, IEEE-488 address, Alpha or Numeric Exponent, plotter Y Hi Limit, Y Lo Limit, Grid, 50/60Hz selection, and Digital Calibration.

SUPPRESS: Allows zeroing of on-range C, C/C_O, or I readings. Allows relative readings to be made with respect to a baseline value.

FILTER:

Code	Readings Weighted	Typical White Noise Reduction	Typical Measurement Use
0	1	None	OFF
1	3	1.7	C or I vs. V
2	9	2.5	C or I vs. V
3	24	5	Steady C, I

MAXIMUM INPUT: 30V peak, DC to 60Hz sine wave.

MAXIMUM COMMON MODE VOLTAGE: 30V maximum, DC to 60Hz sine wave.

INPUT CONNECTOR: Isolated BNC on rear panel.

OUTPUT CONNECTORS: Isolated BNCs on rear panel for VOLTAGE SOURCE OUTPUT, EXTERNAL TRIGGER, and METER COMPLETE. 5-way binding posts on rear panel for ANALOG OUTPUTs, PEN LIFT, GUARD, and Chassis.

EXTERNAL TRIGGER: TTL compatible EXTERNAL TRIGGER and METER COMPLETE.

ENVIRONMENT: Operating: 0° to 40°C, relative humidity 70% non-condensing up to 35°C. **Storage:** –25° to +65°C.

WARM-UP: 2 hours to rated accuracy (see manual for recommended procedure).

POWER: 105–125V or 210–250V (internal switch selected), 50Hz to 60Hz, 15VA max. 90–110V and 180–220V version available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.2kg (6 lbs., 14 oz.).

ACCESSORY SUPPLIED: Two Model 4801 Low Noise BNC Input Cables.

CAPACITANCE (C)

RANGE	RESOLUTION*	ACCURACY* [illegible] 18°–28°C ±(%rdg + counts)	MAXIMUM ALLOWABLE [illegible] DELAY TIME [illegible]
200 pF	10 fF	1.0 + 10	90.00 pA
2 nF	100 fF	0.8 + 2	0.900 nA
20 nF	1 pF	0.6 + 2	9.000 nA

*Exclusive of noise, for STEP V ≥ 0.05V and DELAY TIME ≤ 1 second. For other parameters, derate by (5mV/STEP V) × (DELAY TIME/1 second) in pF at 23°C. Double the derating for every 10°C rise in ambient temperature above 23°C.

TYPICAL PEAK-TO-PEAK NOISE (with supplied cables): ±(0.015% rdg + 0.006pF) × (100mV/STEP V) ± 1 count with FILTER 2, 0.1Hz to 10Hz.

Q/t: Measures non-equilibrium current and leakage current in the device under test during a capacitance measurement.

Display: 3 digits typical; resolution from 0.01fA to 0.01nA per count depending on range, STEP V, and DELAY TIME.

Measurement Time: DELAY TIME/8 or 0.044s, whichever is greater. Sampled at the end of each capacitance measurement.

Accuracy (1 Year, 18°–28°C): ±(1.0% rdg + 2 counts) exclusive of input bias current and noise.

C/C_O: Outputs normalized reading (up to 1.9999) as a ratio of the measured capacitance to a user-stored value of C_O.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.02% rdg + 0.1 count)/°C.

CURRENT (I)

RANGE	RESOLUTION	[illegible]	[illegible]
20 pA	1 fA	1.5 + 14	0.15 + 3
200 pA	10 fA	1.5 + 2	0.15 + 0.3
2 nA	100 fA	0.25 + 6	0.015 + 3
20 nA	1 pA	0.25 + 1	0.015 + 0.3
200 nA	10 pA	0.1 + 4	0.01 + 3
2 µA	100 pA	0.1 + 1	0.01 + 0.3
20 µA	1 nA	0.1 + 4	0.01 + 3
200 µA	10 nA	0.1 + 1	0.01 + 0.3

*When properly zeroed.

NMRR: 70dB on pA ranges, 60dB on nA and µA ranges, at 50 or 60Hz ±0.1%.

VOLTAGE SOURCE (V)

OUTPUT: –20.00V to 20.00V in 0.01V increments.

ACCURACY (1 Year, 18°–28°C): ±(0.2% + 10mV).

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.005% + 200µV)/°C.

MAXIMUM OUTPUT CURRENT: ±2mA; active current limit at <4mA with annunciation.

SETTLING TIME: <3ms to rated accuracy.

NOISE: <(1ppm of output voltage + 100µV) p-p from 0.1 to 10Hz.

STEP VOLTAGE: Selectable as 0.01V, 0.02V, 0.05V, or 0.10V (±2%). Polarity selectable + or –.

DELAY TIME: 0.07s to 199.99s in 0.01s increments (±0.05%).

STEP TIME: DELAY TIME plus 0.04s typical.

WAVEFORM:

- OFF: Outputs 0.0V ±0.01V.
- DC: Outputs the programmed voltage.
- STEP: Outputs changes in increments of STEP V from programmed voltage in either staircase or squarewave.

SQUAREWAVE: Repeatedly toggles between the programmed voltage and the programmed voltage plus STEP V, dwelling at each level for Step Time.

STAIRCASE: Repeatedly increments the output by STEP V until the upper or lower LIMIT is reached, dwelling at each level for Step Time.

ANALOG OUTPUTS

C, I OUTPUT LEVEL: 1V = 10,000 counts on ×1 gain; 1V = 1000 counts on ×10 gain.

V OUTPUT LEVEL: 1V = 10V on voltage source output.

MAXIMUM OUTPUT VOLTAGE: ±2V.

OUTPUT RESISTANCE: 1kΩ.

ACCURACY: ±(0.25% of displayed reading + 2mV).

RESPONSE TIME: Follows display.

ISOLATION: 30V peak from chassis or GUARD to ANALOG OUTPUT LO, which is connected to IEEE COMMON.

C-V Analyzer

- **100kHz, 1MHz, or 100kHz/1MHz test frequencies**
- **Measures capacitance (10fF—20nF) and conductance (0.1nS—1μS)**
- **Internal correction for errors due to cables, connections, and switching paths**
- **Built-in test setup and correction value storage, analysis, and plotter control to minimize computer programming**

IEEE-488

[illegible]

590/100k
100kHz C-V Analyzer with IEEE-488 Interface and two Model 7051-5 BNC Interconnect Cables, 1.5m (5 ft.)

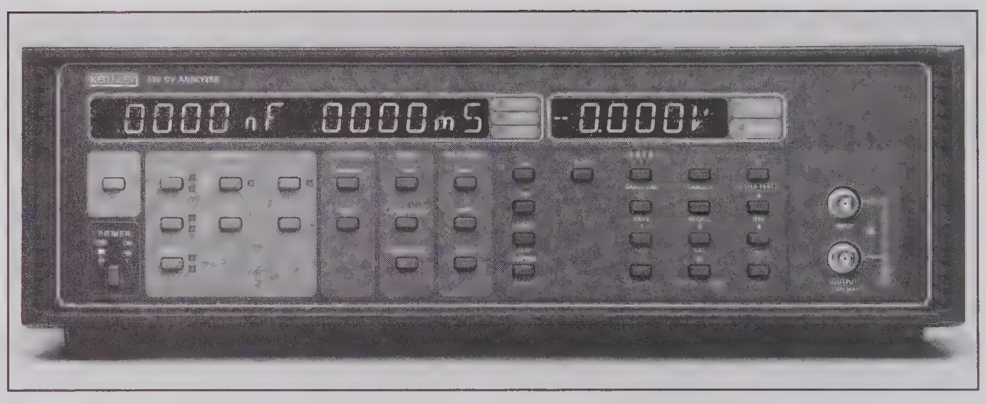
590/1M
1MHz C-V Analyzer with IEEE-488 Interface and two Model 7051-5 BNC Interconnect Cables, 1.5m (5 ft.)

590/100k/1M
100kHz/1MHz C-V Analyzer with IEEE-488 Interface and two Model 7051-5 BNC Interconnect Cables, 1.5m (5 ft.)

590/100k/4
100kHz C-V Analyzer with Calibrated 5904 Adapter and IEEE-488 Interface and two Model 7051-5 BNC Interconnect Cables, 1.5m (5 ft.)

590/100k/1M/4
100kHz/1mHz C-V Analyzer with Calibrated 5904 Adapter and IEEE-488 Interface and two Model 7051-5 BNC Interconnect Cables, 1.5m (5 ft.)

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**



The Keithley 590 C-V Analyzer measures capacitance versus voltage (C-V) and capacitance versus time (C-t) characteristics of semiconductor devices. Unlike other capacitance measurement instruments, the 590 has been tailored to the requirements of semiconductor device testing.

Specifically, it provides:

- 0.1fF sensitivity to test small devices.
- Ranges up to 20nF (at 100kHz, using 5904 adapter) to test large, leaky, or forward biased devices.
- Test signal voltage of 15mV rms.
- Choice of 1MHz frequency for compliance with existing test standards or 100kHz for improved resolution, range, and accuracy.
- Selectable measurement rate (1 to 1000 readings per second) and filter to optimize speed/resolution trade-offs.
- Sophisticated correction for transmission line errors due to device connections.
- Built-in test setup and correction value storage, analysis, and plotter control to minimize computer programming.

Applications

High frequency (100kHz or 1MHz) C-V measurements are commonly applied to test p-n or schottky junction and Metal-Insulator-Semiconductor (MIS) devices for the device characterization and process control. C-V results are highly correlated with performance parameters of functional devices such as FETs, memory cells, CCDs, and isolation structures.

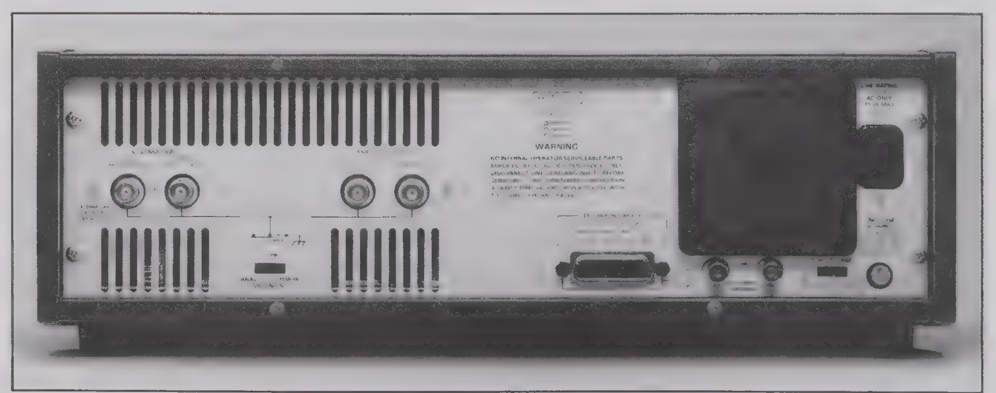
C-V and C-t data is used in the determination of important characteristics such as semiconductor doping profiles, threshold voltage, oxide characteristics, mobile ion density, interface trap density, and minority carrier lifetime.

Measure C-V and C-t, not just Capacitance

The internal voltage source can supply up to 50mA from –20V to 20V with 5mV resolution in the waveforms C-V and C-t measurements require: DC, Stair, Dual Stair, and Pulse. Up to 200V may be supplied and monitored using an external source. Rear panel BNC trigger connectors may be used to coordinate timing with external sources such as the Keithley Model 230.

Excellent Sensitivity and Measurement Range

The excellent sensitivity (0.1fF and 0.1nS) and measurement range (20nF and 20mS) of the Model 590 meet test requirements of even demanding applications such as characterization of very small, very large, leaky, or forward biased devices.



C-V Analyzer 590

To automate high frequency C-V measurements, use the 590 in a Model 82, 82-DOS, or 82-PS/2 System or with the Model 5958 C-V Software.

The Model 590 is available with test frequencies of 1MHz (590/1MHz), or 100kHz (590/100k). The dual frequency Model 590/100k/1M provides the flexibility to select the required measurement frequency at the time of measurement.

All three 590 models use a 15mV rms test signal. Testing semiconductor devices with larger test signals can cause curve shape distortion and loss of detail.

A 1MHz test frequency is traditionally specified in C-V test procedures requiring "high-frequency" device characteristics. In many cases 100kHz C-V measurements are replacing 1MHz as the standard, offering better accuracy (0.12% vs. 0.29%) and reduced errors due to cabling or device series resistance.

Verify Accuracy to the DUT

The 590 achieves its specified measurement accuracy despite the effects of the cables and switching between the C-V instrument and the device-under-test (DUT). The 590 offers not only ZERO to suppress "probes up" offsets, but sophisticated compensation for device connections.

By measuring the precise values of Calibration Capacitors (see page 134) connected through the measurement pathway, the 590 adjusts its display and bus readings to compensate for transmission line errors. Only the linearity, not the characteristic impedance, of the 2-port connection system is assumed.

Up to 7 sets of correction values may be stored internally, and an unlimited number may be transferred through IEEE-488, to correct for each pathway in multiple pin systems.

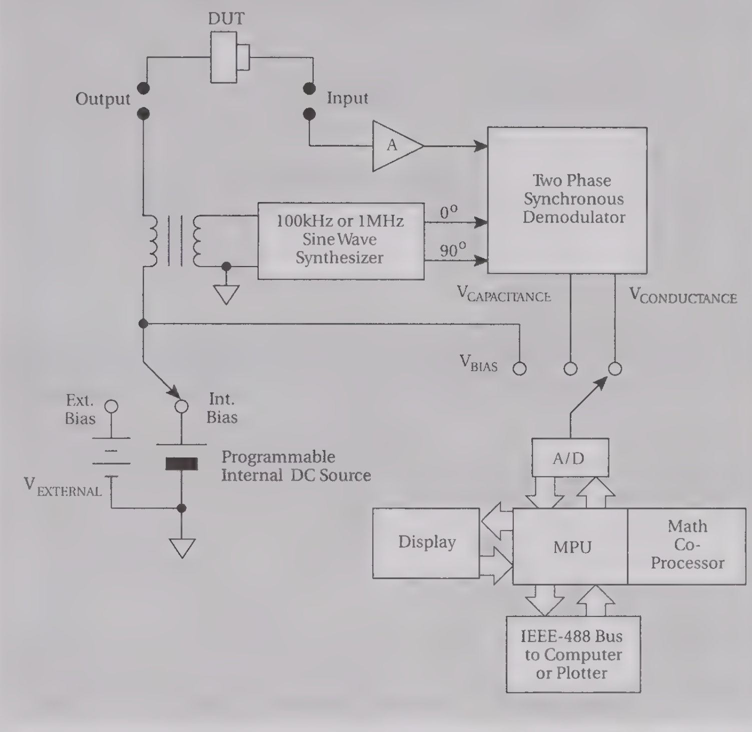
Dual Reading Buffer with Analysis

Acquired readings are stored in the internal 450 point data buffer. A second 450 point data buffer is used for data analysis or output. Built-in analysis routines include Parallel/Series Model, C_{MAX}, C/C_O, $1/C^2$, $C_A–C_B$, and $V_A–V_B$ (see specifications for details).

The rate at which readings are acquired and transferred in to the buffer is selectable to address the variety of test requirements encountered in C-V and permit optimization of speed/resolution tradeoffs.

BUFFERED READINGS	RESOLUTION (digits)	MEASUREMENT RATE (rdg/s)
C	3½	1000
C, G, V	3½	75
C, G, V	4½	1, 10, or 18

FIGURE 1: 590 Block Diagram


DUT
Output
Input
A
Two Phase Synchronous Demodulator
100kHz or 1MHz Sine Wave Synthesizer
0°
90°
$V_{CAPACITANCE}$
$V_{CONDUCTANCE}$
V_{BIAS}
Ext. Bias
Int. Bias
Programmable Internal DC Source
$V_{EXTERNAL}$
A/D
Display
MPU
Math Co-Processor
IEEE-488 Bus to Computer or Plotter

Minimize Computer Programming

Seven different complete front panel setups may be saved and recalled from the internal non-volatile memory to speed changes between setups and assure setup accuracy. For setting measurement parameters using IEEE-488, the 590's TRANSLATOR capability allows you to define your own command syntax, replacing long command strings with simple user-defined names such as "CV1".

You don't need to tie up a computer to plot results either. With the Model 590 completely labelled plots of acquired or analyzed data may be sent to an HPGL plotter using the IEEE-488 bus. No software or computer is needed.

Rear panel analog outputs are also provided for the raw (uncorrected and unanalyzed) C or G values. These analog signals can be viewed on an oscilloscope, an analog plotter, or digitized with a Model 194A to provide high resolution information on capacitive transients.

FIGURE 3: Model 590 Connection Correction Methods

[illegible]	[illegible]	[illegible]	[illegible]
1	Driving point (front panel or bus)	2%	Cables only
2	Transmission line parameters (bus only)	1.5%	Can be used with complex paths
3	Calibration capacitor (bus only)	0.5%	Can be used with complex paths

590 C-V Analyzer

100kHz (4½ Digits)

RANGE	RESOLUTION	ACCURACY (1 Year)[2] 18°–28°C ±(%rdg + counts)	P-P NOISE[5] FILTER ON	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg + counts)/°C	SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts)
2 pF	0.1 fF	$0.12\% + (500 \times G/G_{FS} + 200)$	6 fF	$0.02\% + (20 \times G/G_{FS})$	$0.1\% + (3 \times G/G_{FS})$
2 µS	0.1 nS	$0.12\% + (50 \times C/C_{FS} + 200)$	4 nS	$0.02\% + (7 \times C/C_{FS})$	$0.1\% + (3 \times C/C_{FS})$
20 pF	1 fF	$0.12\% + (260 \times G/G_{FS} + 10)$	6 fF	$0.02\% + (20 \times G/G_{FS})$	$0.1\% + (3 \times G/G_{FS})$
20 µS	1 nS	$0.12\% + (22 \times C/C_{FS} + 10)$	4 nS	$0.02\% + (7 \times C/C_{FS})$	$0.1\% + (3 \times C/C_{FS})$
200 pF	10 fF	$0.12\% + (260 \times G/G_{FS} + 5)$	90 fF	$0.02\% + (20 \times G/G_{FS})$	$0.1\% + (3 \times G/G_{FS})$
200 µS	10 nS	$0.12\% + (22 \times C/C_{FS} + 5)$	60 nS	$0.02\% + (7 \times C/C_{FS})$	$0.1\% + (7 \times C/C_{FS})$
2 nF	100 fF	$0.12\% + (260 \times G/G_{FS} + 5)$	900 fF	$0.02\% + (20 \times G/G_{FS})$	$0.02\% + (2 \times G/G_{FS})$
2 mS	100 nS	$0.12\% + (22 \times C/C_{FS} + 5)$	600 nS	$0.02\% + (7 \times C/C_{FS})$	$0.02\% + (3 \times C/C_{FS})$
20 nF *	1 pF	$0.25\% + (260 \times G/G_{FS} + 5)$[3]	9 pF	$0.1\% + (30 \times G/G_{FS})$	$0.02\% + (2 \times G/G_{FS})$
20 mS	1 µS	$0.25\% + (22 \times C/C_{FS} + 5)$	6 µS	$0.1\% + (10 \times C/C_{FS})$	$0.02\% + (2 \times C/C_{FS})$

Accuracy is maximum limit for Q≥20; typical for Q<20.

*Using Model 5904 20nF/20mS Input Adapter.

1MHz (3½ Digits)

RANGE	RESOLUTION	ACCURACY (1 Year)[2] 18°–28°C ±(%rdg + counts)	P-P NOISE[5] FILTER ON	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg + counts)/°C	SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts)
20 pF	1 fF	$0.29\% + (300 \times G/G_{FS} + 10)$	6 fF	$0.02\% + (20 \times G/G_{FS})$	$0.5\% + (25 \times G/G_{FS})$
200 µS	10 nS	$0.29\% + (120 \times C/C_{FS} + 10)$	40 nS	$0.02\% + (8 \times C/C_{FS})$	$0.5\% + (10 \times C/C_{FS})$
200 pF	10 fF	$0.29\% + (300 \times G/G_{FS} + 5)$	100 fF	$0.02\% + (20 \times G/G_{FS})$	$0.35\% + (40 \times G/G_{FS})$
2 mS	100 nS	$0.29\% + (120 \times C/C_{FS} + 5)$	700 nS	$0.02\% + (8 \times C/C_{FS})$	$0.35\% + (16 \times C/C_{FS})$
2 nF	100 fF	$0.29\% + (300 \times G/G_{FS} + 5)$	200 fF	$0.02\% + (20 \times G/G_{FS})$	$0.35\% + (40 \times G/G_{FS})$
20 mS	1 µS	$0.29\% + (120 \times C/C_{FS} + 5)$	1 µS	$0.02\% + (8 \times C/C_{FS})$	$0.35\% + (16 \times C/C_{FS})$

Accuracy is maximum limit for Q≥20; typical for Q<20.

NOTES:

1. G = conductance reading; C = capacitance reading; G_{FS} = full scale conductance; C_{FS} = full scale capacitance. Range and accuracy designations based on parallel RC model.
2. Front panel accuracy is relative to calibration source accuracy. Add front panel accuracy and source accuracy for total accuracy. Factory calibration source accuracy is 0.06% for 100kHz and 0.08% for 1MHz. CAL is used to cancel initial zero, gain, and phase error terms within 8 hours of measurement or whenever ambient temperature changes by more than 2°C.
3. The 5904 must be calibrated with a particular 590/100k to achieve specified accuracy.
4. "Shunt Capacitance Loading" is additional accuracy with equal shunt load on Output and Input, per 100pF shunt load.
5. Noise specified with 500pF shunt loading on Output and Input. Noise on 2pF and 20pF ranges is typical with 100pF shunt load; 500pF will increase noise no more than ×2. Measured at 10 rdg/s rate.

CAPACITANCE NON-LINEARITY: <0.1% of range, for Q > 20 or D < 0.05, 18°–28°C.

TEST VOLTAGE: 15mV rms ±10%.

TEST FREQUENCY: 590/100k: 100kHz. 590/1M: 1MHz. Tolerance: ±0.1%.

ANALYSIS CAPABILITY

(Programming & output available from front panel or IEEE-488 bus)

READING BUFFERS A and B: Two data buffers allow storage and mathematical manipulation on up to 450 measurement triplets: capacitance, conductance, and voltage. In C vs. t, capacitance and index only are stored (up to 1350 points).

$1/C^2$: Performs the inverse of C^2 on the capacitance data stored in reading buffer.

C/C_O: Allows normalization of capacitance readings stored in reading buffer to a user-programmable reference value C_O.

C_{MAX}: Searches reading buffer for the maximum capacitance value.

$C_A - C_B$: Sequentially computes the difference between corresponding capacitance readings stored in reading buffer A and reading buffer B.

$|V_A - V_B|$: Calculates the corresponding difference in applied voltage for values of capacitance in reading buffer B equal to each value in reading buffer A.

C vs. t: Allows fast measurement of capacitance vs. time (1000 rdg/s).

CABLE COMPENSATION

(Up to 8 setups can be stored in non-volatile memory)

CALIBRATION CAPACITOR COMPENSATION: Corrects for errors due to cables or switching matrix up to 5 meters effective (electrical equivalent) length. Two measurements are made with cables and matrix terminated with precision reference capacitors in place of the DUT. Model 5907 Cable/Matrix Calibration Capacitor Set required. Bus programmable only. **Accuracy:** ±(0.5% + applicable front panel specification), typical.

SINGLE-ENDED CABLE and S-PARAMETER COMPENSATION can also be made. See manual for detailed information.

C-V Analyzer 590

BIAS SOURCE

INTERNAL BIAS SOURCE OUTPUT: –20.000V to +20.000V in 5mV steps.

ACCURACY (1 Year, 18°–28°C): ±(0.05% setting + 10mV) exclusive of loading errors.

DC OUTPUT RESISTANCE: 5Ω maximum.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.005% + 1mV)/°C.

MAXIMUM OUTPUT CURRENT: ±50mA.

SETTLING TIME: <1ms to 1% of final value.

NOISE: Typically <200µV p-p, 0.1Hz-1MHz; 3mV p-p to 75MHz.

BIAS WAVEFORM:
- DC: Outputs the programmed value.
- STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V.
- DUAL STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V, then back to FIRST BIAS V.
- PULSE: Outputs pulse train; amplitude increments by BIAS STEP V from FIRST BIAS V to LAST BIAS V (each pulse is from DEFAULT BIAS V to FIRST BIAS V for duration of STEP TIME, then back to DEFAULT BIAS V). Also programmable for single pulse.
- EXT: Allows application of external bias source (via VOLTAGE BIAS INPUT).

BIAS PARAMETERS: FIRST BIAS V, LAST BIAS V, DEFAULT BIAS V, BIAS STEP V, START TIME, STOP TIME, STEP TIME, COUNT.

BIAS STEP V: Programmable in 5mV steps to 20V. Polarity selectable + or –.

START TIME: After transition from DEFAULT BIAS V to FIRST BIAS V, START TIME must elapse before first measurement. Programmable in increments of 1024µs from 1 to 65,536 increments. Accuracy: ±(0.1% + 1ms).

STEP TIME: The period between the transition of BIAS STEP V and the start of the next measurement. Programmable in increments of 1024µs from 1 to 65,536 increments. Accuracy: ±(0.1% + 1ms).

STOP TIME: The period between the end of the final measurement and the transition from LAST BIAS V to DEFAULT BIAS V. Programmable in increments of 1024µs from 1 to 65,536 increments. Accuracy: ±(0.1% + 1ms).

VOLTAGE BIAS MONITOR: Rear panel output terminals allow monitor of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. Level: 1V = 1V out. Output Resistance: 1kΩ.

VOLTAGE BIAS DISPLAY: Front panel 4½-digit display allows direct readback of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. Accuracy: ±(0.05% + 5 counts). Temperature Coefficient: ±(0.005% + 0.1 count)/°C.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, E1, C0 (for stand alone plotting C28 is used).

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Filter, Frequency, Bias Waveform, Bias Parameters, Plotting, Plotter Parameters, EOI, Trigger, Terminator, 450 Data Point Storage, Calibration, Cable Correction, Display, Status, Service Request, Self Test, Output Format.

TRANSLATOR: Up to 250 bytes of definitions allow variable passing, definition decomposition and listing.

GENERAL

DISPLAY: Three 4½-digit displays for capacitance, conductance, and voltage bias.

RANGE: Manual or autoranging (for rates up to 18 rdg/s); 10% overrange allowable.

OVERRANGE INDICATION: Display reads OFLO.

AVAILABLE MEASUREMENT RATES (to internal buffer): 4½-Digit: 1, 10, and 18 rdg/s. **3½-Digit:** 75 and 1000 rdg/s.

FILTER: 1-pole analog; pole at 37Hz. Filters both capacitance and conductance signals. For FILTER off, multiply p-p noise specification by 5. CAL: Initiates self-calibration to internal reference capacitor. Used to cancel initial zero, gain, and phase errors.

ZERO: Allows zeroing of on range readings. Allows relative readings to be made with respect to a baseline value.

MAXIMUM OVERLOAD: OUTPUT, Voltage Bias Input: 200V internally fused at 1/8A. INPUT: Clamped by diodes to ±0.7V. Maximum current 200mA. Analog Outputs: 15V.

MAXIMUM COMMON MODE VOLTAGE (INPUT and OUTPUT, Voltage Bias Input): 30V rms, DC to 60Hz. Rear panel switch allows connection of INPUT low to chassis.

ANALOG OUTPUTS (Capacitance and Conductance):
- **Level:** 2V output at full range.
- **Initial Offset:** ±25mV.
- **Output Resistance:** 1kΩ.
- **Response Time:** 1ms to 1% of final value with filter off; 25ms maximum with filter on.

PLOTTER: Digital plotter output controls HP7470A plotter or equivalent using HPGL® via IEEE-488 for real-time plotting of all measurements as well as results of math computations, with grids and labels. Talks to plotter on address 05. HPGL® commands used are IN, IP, IW, PA, PD, PU, SC, SI, SP.

FRONT PANEL SETUPS: Up to 7 front panel setups can be stored in nonvolatile memory.

EXTERNAL TRIGGER: TTL compatible External Trigger Input and Output.

INPUT CONNECTORS: Isolated BNC for INPUT and Voltage Bias Input.

OUTPUT CONNECTORS: Isolated BNCs for OUTPUT, Voltage Bias Monitor, Analog Outputs, and External Trigger.

ENVIRONMENT: Operating: 0°–50°C, relative humidity 70% non-condensing up to 35°C. **Storage:** –25° to +65°C.

WARM-UP: 1 hour to rated accuracy.

COOLING: Internal fan and filter for forced air cooling.

POWER: 105–125V or 210–250V (external switch selected), 50Hz to 60Hz, 100VA maximum. 90–110V and 180–220V version available upon request.

DIMENSIONS, WEIGHT: 133mm high × 435mm wide × 448mm deep (5¼ in. × 17⅛ in.× 17¼ in.). Net weight 9.1kg (20 lbs.).

ACCESSORIES AVAILABLE

CABLES

7007-1	Shielded IEEE-488 Digital Cable, 1m (3.3 ft.)
7007-2	Shielded IEEE-488 Digital Cable, 2m (6.6 ft.)
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5	BNC Interconnect Cable, 1.5m (5 ft.)
7051-10	BNC Interconnect Cable, 3m (10 ft.)

ADAPTER

5904	20nF/20mS Adapter

CALIBRATION

5905	Calibration Sources for 590/1M
5906	Calibration Sources for 590/100k/1M/4
5907	Cable/Matrix Calibration Sources
5909	Model 82 Calibration Sources

SOFTWARE

5956	Simultaneous C-V Software (for HP computers)
5957	Simultaneous C-V Software (for DOS computers)
5958	C-V Software Utilities (for DOS computers)

RACK MOUNT KITS

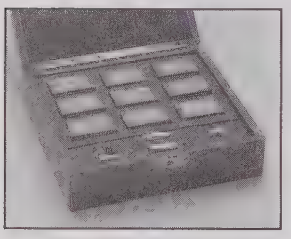
2288	Fixed Rack Mount Kit
2289	Slide Rack Mount Kit

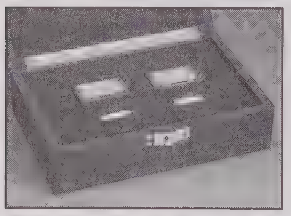
See page 163 for descriptions of all accessories.

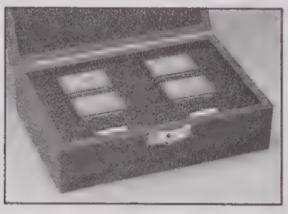
Calibration/Verification Sources

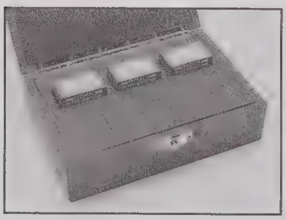
- **Complete sets of capacitance and conductance sources for Models 590, 595, and 82.**
- **Use with Models 590 and 82 to correct for cable or other connection errors.**
- **Specially designed for stability and NIST traceability.**

Keithley calibration and verification sources have been designed to calibrate capacitance measurement equipment operating at frequencies to 1MHz. The sources are configured for 3-terminal (shielded) capacitance and conductance measurements. They use stable glass dielectric capacitors and high-quality film resistors, both with very low residual impedance. The sources are specified at 1kHz, 100kHz, and 1MHz, and the conductance sources are specified at DC, 100kHz, and 1MHz. Their calibration is traceable to the National Institute of Standards and Technology. The Model 5907 Calibration Capacitors can be used to correct for 1MHz connection errors in the Model 590. Connect the known capacitance source at the DUT end of the cable or switching matrix. Enter the value of this source into the 590; it will adjust the display and the bus reading to the exact value of the source. Up to seven sets of correction values may be stored in the 590's internal non-volatile memory, permitting correction values for seven cable configurations or seven pin connections. After this procedure, total errors can be reduced to less than 0.5%, even with up to 15 meters of connecting cable or a switch matrix in the connecting path.









ORDERING INFORMATION

5905 To calibrate/verify 590/1M

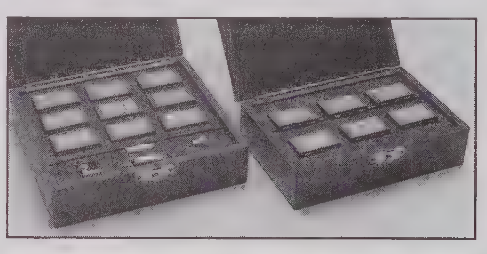
5906 To calibrate/verify 590/100k, 590/1M, 590/100k/1M, 5904, 595

5907 To calibrate/verify Cable/Matrix

5909 To calibrate/verify Model 82, 82-DOS, 82-PS/2

5955 To calibrate/verify 595

See page 221 for complete ordering information, or call **1-800-552-1115** (U.S. only).



5906	ACCURACY (ppm), 28° ±2°C			
	24 HOURS		90 DAYS	
VALUE	100kHz	1MHz	100kHz	1MHz
1.8 nF	465	645	640	820
470 pF	375	420	550	595
180 pF	375	390	550	565
47 pF	375	380	550	555
18 pF	375	375	550	550
4.7 pF	375	375	550	550
18 mS	300	300	375	375
1.8 mS	300	300	375	375
180 µS	300	300	375	375

DIMENSIONS, WEIGHTS: Each calibration source is 35mm × 57mm × 44mm (1⅜ in. × 2¼ in. × 1¾ in.). Carrying case with calibration sources is 248mm × 229mm × 73mm (9¾ in. × 9 in. × 2⅞ in.). Net weight 2.16kg (4 lbs. 12 oz.).

5905	ACCURACY (ppm), 28° ±2°C			
	24 HOURS		90 DAYS	
VALUE	100kHz	1MHz	100kHz	1MHz
18 nF	490		665	
4. nF	470		645	
1.8 nF	465	645	640	820
470 pF	375	420	550	595
180 pF	375	390	550	565
47 pF	375	380	550	555
18 pF	375	375	550	550
4.7 pF	375	375	550	550
1.5 pF	375	375	550	550
0.5 pF	375	375	550	550
18 mS	300	300	375	375
1.8 mS	300	300	375	375
180 µS	300	300	375	375
18 µS	300	300	375	375
1.8 µS	300	300	375	375

DIMENSIONS, WEIGHTS: Each calibration source is 35mm × 57mm × 44mm (1⅜ in. × 2¼ in. × 1¾ in.). Two carrying cases provided. One case with calibration sources is 248mm × 229mm × 73mm (9¾ in. × 9 in. × 2⅞ in.), net weight 2.16kg (4 lbs. 12 oz.). Second case with calibration sources is 248mm × 165mm × 73mm (9¾ in. × 6½ in. × 2⅞ in.), net weight 1.20kg (2 lbs. 10 oz.).

5907	ACCURACY (ppm), 28° ±2°C			
	24 HOURS		90 DAYS	
VALUE	100kHz	1MHz	100kHz	1MHz
1.8 nF	465	645	640	820
470 pF	375	420	550	595

DIMENSIONS, WEIGHTS: Each calibration source is 35mm × 57mm × 44mm (1⅜ in. × 2¼ in. × 1¾ in.). Carrying case with calibration sources is 248mm × 229mm × 73mm (9¾ in. × 9 in. × 2⅞ in.). Net weight 1.20kg (2 lbs. 10 oz.).

5909	ACCURACY (ppm), 28° ±2°C			
	24 HOURS		90 DAYS	
VALUE	100kHz	1MHz	100kHz	1MHz
1.8 nF	465	645	640	820
470 pF	375	420	550	595
180 pF	375	390	550	565
47 pF	375	380	550	555

DIMENSIONS, WEIGHTS: Each calibration source is 35mm × 57mm × 44mm (1⅜ in. × 2¼ in. × 1¾ in.). Carrying case with calibration sources is 248mm × 229mm × 73mm (9¾ in. × 9 in. × 2⅞ in.). Net weight 2.16kg (4 lbs. 12 oz.).

5955	ACCURACY		
	28° ±1°C, 1 YEAR		INSULATION
VALUE	DC–100kHz	DC–1MHz	RESISTANCE
18 nF	0.2 %	0.4 %	10^{12} Ω min.
1.8 nF	0.2 %	0.2 %	10^{13} Ω min.
180 pF	0.2 %	0.2 %	10^{14} Ω min.

DIMENSIONS, WEIGHTS: Each calibration source is 35mm × 57mm × 44mm (1⅜ in. × 2¼ in. × 1¾ in.). Carrying case with calibration sources is 248mm × 165mm × 73mm (9¾ in. × 6½ in. × 2⅞ in.). Net weight 1.20kg (2 lbs. 10 oz.).

GENERAL

ACCURACY: Typical accuracies for >90 days from calibration: Add 350ppm × √years to 24 hour capacitance specifications. Add 150ppm × √years to 24 hour conductance specifications.

CAPACITANCE FROM EITHER TERMINAL TO CASE: 3.5pF maximum; 7.0pF maximum for 18nF and 4.7nF.

TEMPERATURE COEFFICIENT OF DIRECT CAPACITANCE (0°–50°C): ±140ppm/°C typical.

MAXIMUM VOLTAGE: ±300V.

INSULATION RESISTANCE (terminal to terminal or case): 10^{12}Ω min. (18nF, 4.7nF); 10^{13}Ω min. (1.8nF, 470pF); 10^{14}Ω min. (180pF or less).

TERMINALS: Two male BNC push-on connectors spaced on 1-inch centers.

OPERATING ENVIRONMENT: 0° to 50°C; 0% to 70% relative humidity up to 35°C.

STORAGE ENVIRONMENT: –25°C to +65°C.

Hall Effect Measurements

Integrated Solutions

Keithley offers a wide selection of sensitive instruments and systems for Hall Effect and related measurements of both high- and low-resistivity materials. Depending on the individual application and budget, a do-it-yourself system using individual Keithley components may be selected and easily connected to form a system. Or a ready-to-use system complete with software may be chosen. This section is intended to provide the background needed to make an informed choice.

Generally, it's best to choose a system with capabilities somewhat greater than those required for the immediate application so it addresses future as well as present needs. Keithley's applications engineers are available to discuss the costs and advantages of buying a turn-key system versus configuring a system and writing software.

Model 705/7065 Hall Effect Card/Scanner

The 705/7065 is a Hall Effect card in a small scanner mainframe. The card contains four sensitive DC amplifiers and all switching needed. These amplifiers are switched to connect the card to the sample for making Hall or van der Pauw resistance measurements. The user can select either high or low resistivity settings via software.

Model 80 Hall Effect Package

This system includes a complete set of measurement electronics, switching, cabling, and sample software in the manual for users who wish to configure their own systems. The Model 80 is based on the 705/7065 Card and Scanner, and offers the same measurement capabilities in a very affordable package.

Model 925 Hall Effect Systems

The Model 925 Hall Effect Systems include all the hardware and software required to perform precise Hall Effect and related measurements. In addition to all necessary measurement electronics, switching and cabling, the 925A room temperature system has a built-in electromagnet and full menu-selectable software. The 925B, developed for dual-temperature Hall Effect testing, also includes a 77K dewar.

Model 926 Differential Hall Effect Profilers

Like the Model 925 Hall Effect Systems, the Model 926 Differential Hall Effect Profilers are turn-key systems complete with all needed hardware and software. The Model 926A is a room temperature profiling system with etching capabilities that allow the researcher to obtain a profile of Hall coefficient, van der Pauw resistances, mobility and carrier concentration as a function of depth. The 926B offers the same etching capabilities as the 926A and a 77K dewar for dual temperature testing.

Factors in Choosing a System: Resistance Range

Many testing situations require a system capable of precise measurements over a wide range of resistivities. The range of resistivities of the materials being studied determines the appropriate choices of current-sourcing and voltage-measuring instruments.

For example, testing high resistivity materials such as lightly-doped samples, semi-insulating GaAs, etc., requires a precision low-level, low-noise current source with a high effective output resistance. For very high resistances (on the order of 1012Ω), a system utilizing driven guards may be required. This is necessary to ensure that virtually all the current goes through the sample, not through any shunt resistance. The driven guard connection also minimizes the time constant of the measurement.

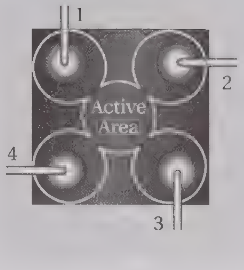
Testing low resistivity samples such as heavily-doped materials or metals requires a higher-value precision current source and a very sensitive voltage-measuring instrument.

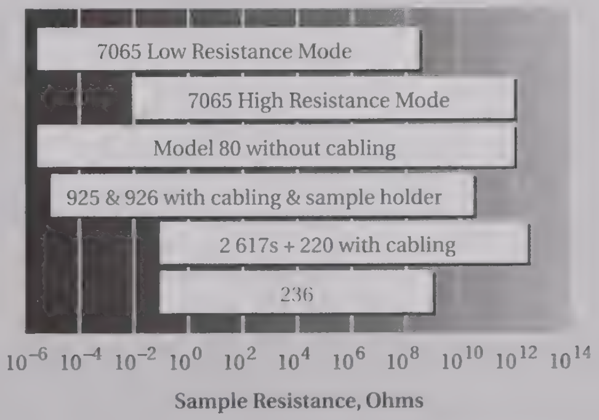
AC vs. DC

A quality, low-noise DC system that is capable of measuring samples with a wide range of resistivities is usually the best choice. While AC measurements are sometimes used for low resistivity testing, this technique makes the results dependent on time constants and the degree to which all contacts are non-rectifying.

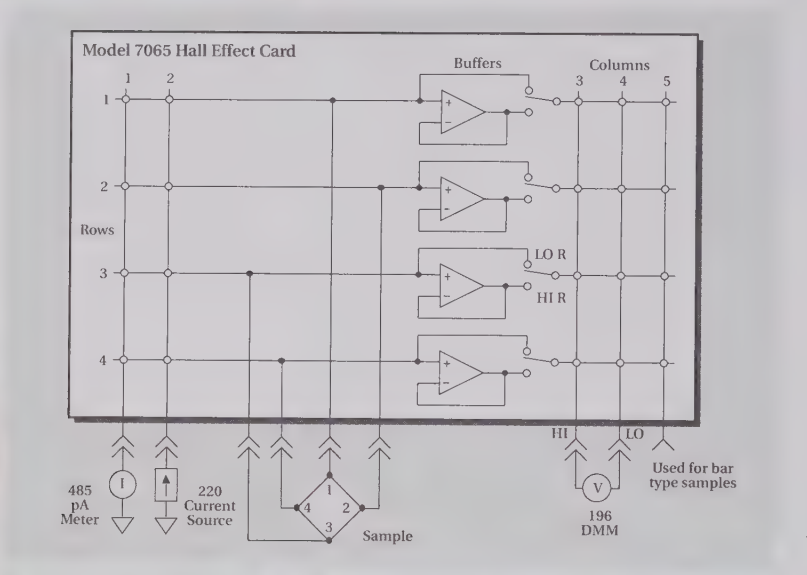
Van der Pauw Resistance Measurements

The sheet resistance of the same cloverleaf sample can be measured easily by applying the current to two adjacent terminals (for example, contacts #2 and #3) and reading the voltage at the two opposite terminals (contacts #1 and #4). While no magnetic field is needed for the resistance measurement, the researcher can easily determine the sheet magneto-resistance by making a series of sheet resistance measurements at various magnetic fields.





705/7065 Hall Effect Card/Scanner



Building blocks for an economical measurement system

The Model 7065 Hall Effect Card is intended for those who want to assemble their own economical Hall test systems. It also forms the foundation of the Model 80 Hall Effect Package. The sensitivity and capabilities of this card are unmatched by any other system or Hall Effect electronics package.

The 7065 is a signal conditioning card designed to buffer test signals from the Hall sample to the measurement instrumentation, and to switch current from a source to the Hall sample. When used with Keithley's 705 scanner mainframe, the 7065 provides the switching capability to measure Hall voltages as low as 50nV and sample resistances in excess of $10^{12}\Omega$. The Model 705 scanner has capacity for two switching cards, allowing up to 20 channels of 2-pole switching.

All the accessories needed to connect the sample holder, scanner, instruments, and controller are included, simplifying connections. The 7065 is connected directly to the sample, and all instruments are connected via the IEEE-488 bus to the controller. Examples of resistivity and Hall voltage measurement programs are included in the 7065 Instruction Manual.

The Model 7065 can be operated in either a low resistivity or a high resistivity mode. In the high resistivity mode, input impedance is greater than 100TΩ, input bias current is less than 150fA, and output resistance is less than 60Ω. Input voltage ranges in both operating modes is +8V to –8V. If higher voltage is desired, Keithley recommends using a 220/617 system. Cabling and sample connections must be carefully designed to make full use of the 7065's capabilities. Refer to Keithley's Low Level Measurements handbook for guidance in designing these connections.

ORDERING INFORMATION

705/7065
20-Channel Scanner Mainframe with Hall Effect Card

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

CONFIGURATION

Input characteristics and output matrix configuration for van der Pauw or Hall bar measurements. Input characteristics selectable for either low resistivity or high resistivity samples.

LOW RESISTIVITY MODE

INPUT VOLTAGE OPERATING RANGE: +8 to –8V.

INPUT IMPEDANCE: >10GΩ in parallel with <420pF.

INPUT BIAS CURRENT: <100pA.

INPUT VOLTAGE NOISE: <50nV p-p, 0.1 to 10Hz bandwidth.

INPUT TO OUTPUT RESISTANCE: <30Ω.

HIGH RESISTIVITY MODE

INPUT VOLTAGE OPERATING RANGE: +8 to –8V.

INPUT IMPEDANCE: >100TΩ in parallel with <3pF.

INPUT BIAS CURRENT: <150fA at 23°C. Doubles approximately every 10°C rise in ambient room temperature.

INPUT VOLTAGE NOISE: <10µV p-p, 0.1 to 10Hz bandwidth.

OUTPUT RESISTANCE: <60Ω.

GENERAL

MAXIMUM COMMON MODE VOLTAGE (analog ground to earth ground): 30V peak, DC to 60Hz sine wave.

ISOLATION: Analog ground to earth ground: $>10^9\Omega$ in parallel with 150pF.

WARM-UP: 1 hour to rated specifications.

ENVIRONMENT: Operating: 0°-35°C, up to 70% R.H. Storage: –25° to +65°C.

CONNECTORS:
Current Source Input: Two-lug female triaxial. Input HI to LO clamped at +12V. **Maximum Input:** 100mA.
Sample Inputs: Four two-lug female triaxial. Outer shell is analog ground. Inner shield is driven guard. **Maximum Input Overload (HI to analog ground or GUARD to analog ground):** +12V.
Current Monitor Output: Insulated female BNC.
Measurement Outputs: Spring-loaded terminals. Accepts AWG #18 to #24 wire. **Maximum Load:** 1mA.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1 in. × 4 in. × 10 in.). Net weight: 434kg (15.5 oz.).

ACCESSORIES SUPPLIED:

4801	Low Noise Input Cable
6167	Guarded Input Adapter
7024-3	Triaxial Cable (3 ft.)
7024-10	Triaxial Cable (10 ft.)
4802-10	Low Noise Input Cable (10 ft.)
7025-10	Triaxial Input Cable (10 ft.) (5 supplied)
7008-6	IEEE-488 Cable (6 ft.)
4851	BNC Shorting Plug
SC-72-0	Single Conductor Insulated Wire, black (4 ft.) (2 supplied)
SC-72-9	Single Conductor Insulated Wire, white (4 ft.)
BG-5	Single Banana Plug, black (2 supplied)
BG-10-1	Single Banana Plug, white
BG-7	Double Banana Plug, black
SC-8	2-Conductor Cable w/shield (10 ft.)

All specifications are 1 year, 18°-28°C, installed in scanner mainframe.

Hall Effect System

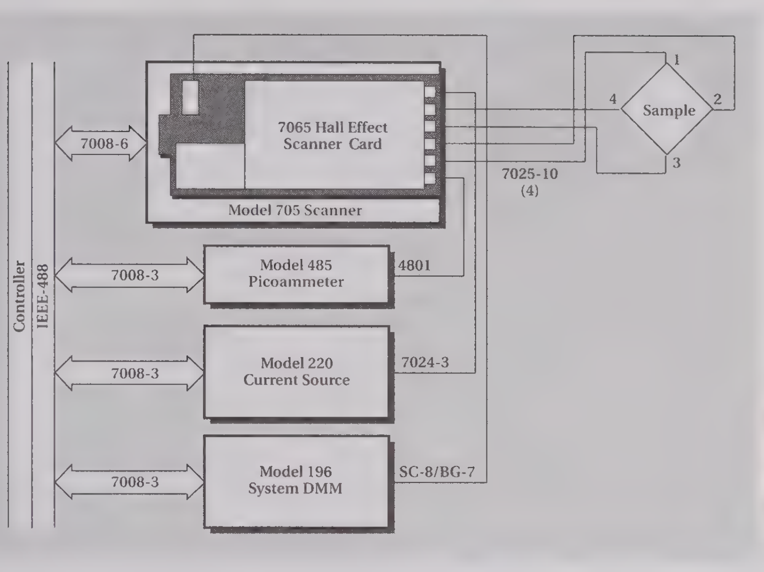
Model 80

Get all the pieces in one convenient package

Keithley offers researchers all the test and measurement instruments, accessories and controller interfaces needed to make accurate Hall/van der Pauw measurements in one convenient, economical package. The Model 80 Hall Effect Package includes:

- Model 705 Scanner Mainframe—houses the 7065 Hall Effect card.
- Model 7065 Hall Effect Card with all accessories—switches and buffers Hall voltage and resistance measurements.
- Model 196 Programmable DMM—measures voltage.
- Model 220 Programmable Current Source—provides source of current.
- Model 485/4853 Picoammeter and IEEE-488 Interface—measures the current actually flowing through the sample.
- Model 7008-3 IEEE-488 Cable (3 supplied)

The Model 7065 Hall Effect Card is the heart of the Model 80 Hall Effect Package. It is designed to buffer test signals from the Hall sample to the measurement instrumentation and to switch current from the current source to the Hall sample. For added convenience, the Model 7065 Instruction Manual includes sample resistivity and Hall voltage programs.



This electronics system has the sensitivity and precision needed to meet a wide variety of Hall system needs, including Hall and resistivity measurements at high temperatures. It may also be used in systems to measure Hall characteristics of high temperature superconductors.

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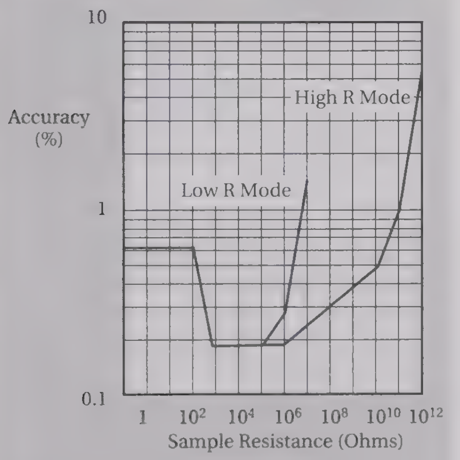
Model 80
Hall Effect System

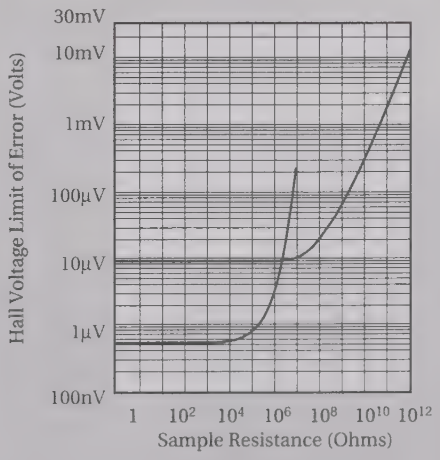
These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

RESISTIVITY MEASUREMENT ACCURACY



Resistivity accuracies are based on sample excitation voltage which produces no more than 1mW power dissipation in sample; 5V maximum for high resistivity mode, 3V maximum for low resistivity mode.

HALL VOLTAGE LIMIT OF ERROR



Assumes 196 System DMM is on 300mV range for both modes; default resolution and filters.

For better performance below 500nV in the low resistivity mode, a Model 182 Nanovoltmeter is recommended in place of the Model 196 System DMM.

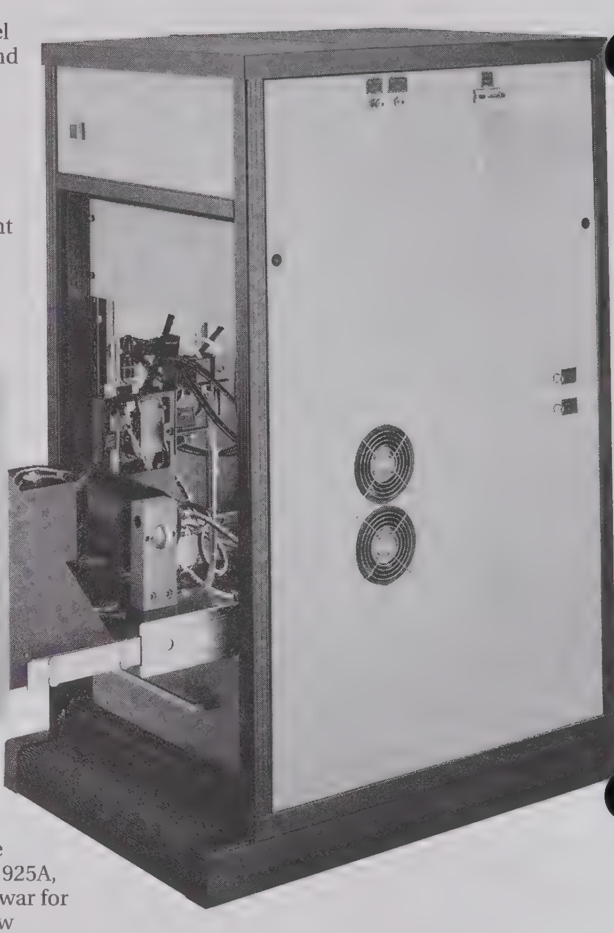
Assumes device under test is at room temperature (18°–28°C).

These charts indicate performance at the measuring terminals. In order to obtain these specifications at the sample, cabling and fixturing to the sample must be done correctly to avoid degrading the signal. These curves do not include the effects of external connections to the sample.

925,926 Hall Effect Systems

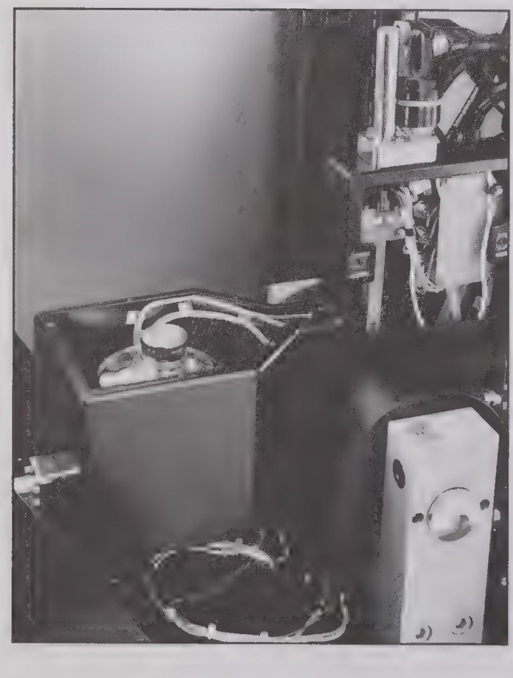
Turn-key Hall Effect systems and differential Hall profilers offer superior value and performance.

Keithley offers two versions of the Model 925 Hall Effect System. Both the 925A and 925B versions measure van der Pauw resistivity and Hall coefficient of a fixed sample and translate the information into carrier concentration and mobility. Once the measurement process is complete, data is stored in raw voltage format. The user can then apply different analysis routines and calculations, without repeating the measurement.



The 925A is a fully-configured room temperature measurement system suitable for Hall Effect measurements on a wide variety of semiconductor materials, including III-V, II-VI, and silicon. It includes all the measuring instruments required for a variety of Hall and van der Pauw measurements: current source, sensitive digital multimeter, 7065 Hall Effect card in a 705 scanner mainframe, electromagnet with adjustable supply, sample holder, easy-to-use menu-driven software, and all necessary cables.

The 925B is a dual temperature Hall Effect measurement system. It offers the same equipment and capabilities as the 925A, with the addition of a liquid nitrogen dewar for assessing the behavior of materials at low temperature (77K). At room temperature, mobility is limited by both impurities and phonon scattering (which is due to the thermal vibration of the crystal lattice). Reducing the temperature to 77K eliminates much of the phonon scattering, while impurity components remain the same. Therefore, a material's mobility at 77K is a very important indicator of its purity. The 925B's 300ml dewar holds enough liquid nitrogen for 2½ to 3 hours of work without refilling.



The Model 926A and 926B Differential Hall Effect Profilers have the capability to do a sequence of van der Pauw resistivity, and Hall coefficient measurements, from which mobility and carrier concentration may be calculated. By etching away a layer of the sample between each set of tests, these systems provide differential Hall Effect measurements of these parameters as a function of depth. The Model 926A offers researchers all the capabilities of the Model 925A Hall Effect System for room temperature measurements. In addition, it includes the hardware, software and material handling capabilities necessary to etch the sample and provide a profile of Hall coefficient, van der Pauw resistances, mobility and carrier concentration vs. depth. The Model 926B has all the profiling and measurement capabilities of the Model 926A, plus a 300ml liquid nitrogen dewar for dual temperature analysis.

The two most commonly-used methods for differential Hall Effect measurements are etching and anodic stripping. While both have the same function—reducing the thickness of the material in a controlled manner—each step of the process is typically five to ten times faster when using etching rather than anodic stripping. Etching is also simpler and more versatile than anodic stripping in most cases; it can be done in the dark and with a wider variety of materials.

The software that accompanies Keithley's Model 926 Profilers can automatically calculate etching times which produce a significant difference in sheet resistance between steps. Typically, this should be in excess of 1% difference in successive sheet resistances to allow good resolution by the measurement electronics and to minimize noise and variations in the final profiles. This can correspond to etch steps as small as 5nm for materials where the sheet resistivity varies rapidly with depth.

The Model 926 Profilers use fresh etch solution for each step of the etching process. This prevents the etch solution from degrading as the sample dissolves in it. The units' rapid fill and empty times promote more uniform etching across the surface of the sample. Fresh rinse water is used after each etch, and the system uses temperature-stabilized gas to dry the sample to assure researchers of greater accuracy.

While C-V (Capacitance-Voltage) and other measurements (SIMS, spreading resistance, etc.) can also provide carrier concentration profiling information, differential Hall Effect profiling techniques offer some significant advantages. For example:

- Superior accuracy is obtained on highly doped materials where it is difficult to make a good diode structure.
- When thick layers are used that would require voltage in excess of the breakdown limits to get a valid C-V curve.
- Narrow-band-gap semiconductors.
- Hall measurements provide data on mobility, which C-V measurements can't provide directly.

The 925 Hall Effect Systems and 926 Differential Hall Profilers are designed for easy set-up and operation. Each includes all the measuring instruments needed, a magnet with programmable supply, sample holder and menu-driven software with programs for a variety of Hall Effect and van der Pauw measurements. All plumbing and valves for supplying etch solutions, gases, etc. are included with those systems that require them. The system arrives configured, assembled, and tested. The user just plugs it in, mounts the sample, connects a computer, supplies any necessary gases and fluids, and turns it on.

The 925 and 926 systems provide 40nV sensitivity per stored data point. Each data point is the average of ten readings from the Model 196 voltmeter. The system reverses the test current on each measurement, eliminating errors due to thermal EMFs in the voltage path. The system determines the necessary settling time before making measurements. Test results are written to disk after each step.

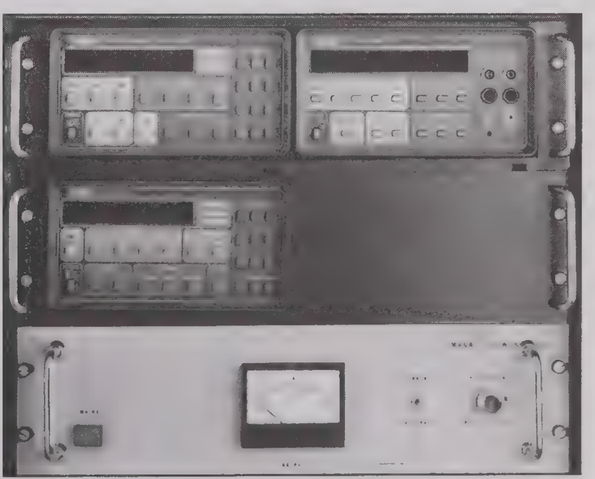
In use, these systems select the appropriate current level to provide reliable resistance readings with minimal self-heating. The user can easily optimize his system for samples with resistances ranging from a few μΩ to many GΩ using the menu-driven software. Depending on material, doping and sample thickness, this resistance range can correspond to carrier concentrations ranging from $10^9/cm^3$ to more than $10^{22}/cm^3$.

The sensitive DC measurement technology behind the 925 and 926 systems means there is no need to worry about time constant effects of bulk and surface carrier trapping, possible AC rectification of currents due to less-than-ideal contacts, or errors due to AC currents through stray capacitance. Since these systems use Keithley active current sources, current flowing isn't dependent on the resistance of the path or on voltage drops along the current path.

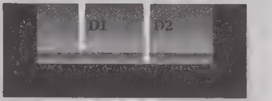
The 925 and 926 systems include a 0.35T Oxford Instruments N38 electromagnet with an adjustable supply, allowing the field to be adjusted to maintain the product of mobility and field strength under unity. This assures that data is taken in the linear region of the Hall Effect.

These systems follow a testing sequence that cancels out all effects of current and voltage offsets, residual magnetic fields, or asymmetries in the magnetic field or the sample. At each field level, a sequence of 24 measurements (each the average of ten readings) is made. Sheet resistivity is calculated using an iterative procedure to solve LaPlace's equation for the potential distribution within the sample. No simplifying assumptions about the sample are necessary to obtain accurate results. An optional data filtering routine in the software allows the user to throw out any Hall voltages that differ from others by more than 20% in order to obtain more reliable figures on highly asymmetric samples.

With the optional 925-SOURCE source code and ASYST 1234 software, users can easily modify the software, menu choices or calculations using English-language-like commands.



DIFFERENTIAL HALL MEASUREMENTS

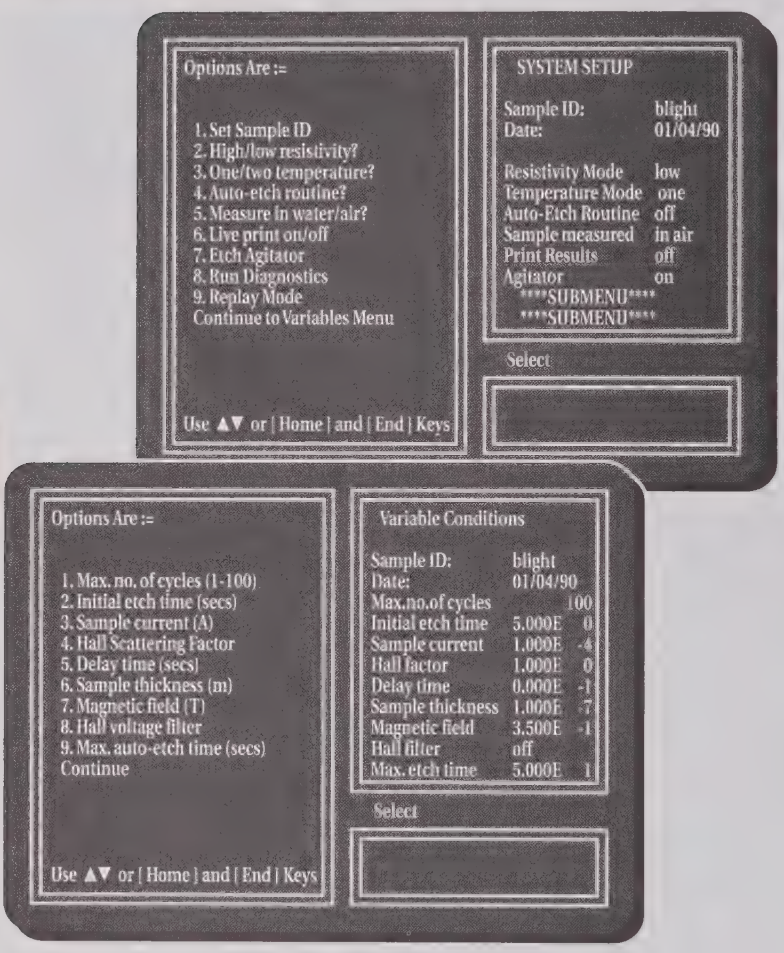


The sample is etched in layers and measurements are taken at each layer.

STEPS:

1. Sample is etched to depth D1.
2. Hall coefficient and resistivity are measured at D1.
3. Sample is etched to depth D2.
4. Hall coefficient and resistivity are measured at D2.
5. Carrier concentration and mobility in the region between D1 and D2 are calculated using differentials between measurements at D1 and measurements at D2.

Hall Effect Systems


Options Are :=
1. Set Sample ID
2. High/low resistivity?
3. One/two temperature?
4. Auto-etch routine?
5. Measure in water/air?
6. Live print on/off
7. Etch Agitator
8. Run Diagnostics
9. Replay Mode
Continue to Variables Menu
Use ▲▼ or | Home | and | End | Keys

SYSTEM SETUP

Sample ID: blight
Date: 01/04/90

Resistivity Mode low
Temperature Mode one
Auto-Etch Routine off
Sample measured in air
Print Results off
Agitator on
****SUBMENU****
****SUBMENU****

Select

Options Are :=
1. Max. no. of cycles (1-100)
2. Initial etch time (secs)
3. Sample current (A)
4. Hall Scattering Factor
5. Delay time (secs)
6. Sample thickness (m)
7. Magnetic field (T)
8. Hall voltage filter
9. Max. auto-etch time (secs)
Continue
Use ▲▼ or | Home | and | End | Keys

Variable Conditions

Sample ID: blight
Date: 01/04/90
Max.no.of cycles 100
Initial etch time 5.000E 0
Sample current 1.000E -4
Hall factor 1.000E 0
Delay time 0.000E -1
Sample thickness 1.000E -7
Magnetic field 3.500E -1
Hall filter off
Max. etch time 5.000E 1

Keithley's advanced Hall Effect measurement technology ensures fast start-ups, easy operation, and high accuracy.

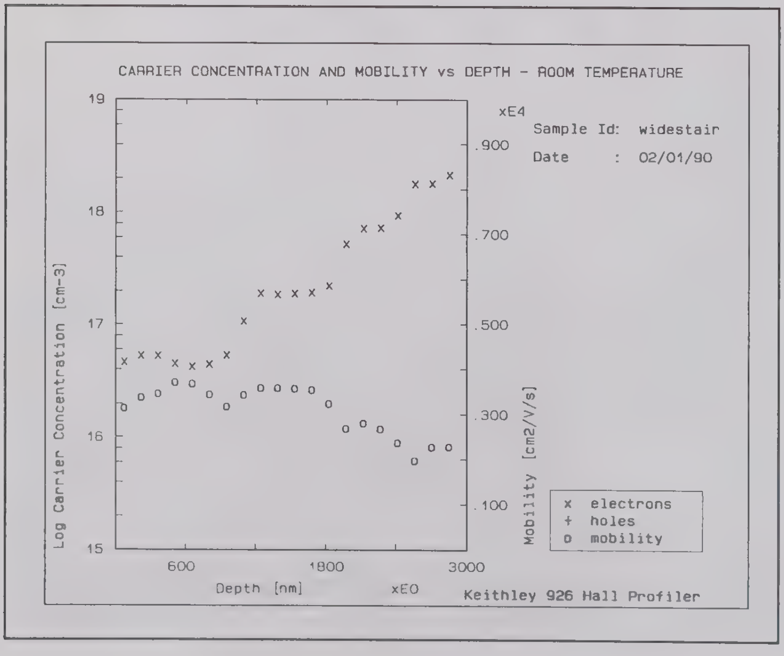
Keithley's Model 925/926 systems have been engineered to simplify the most complex Hall measurement and profiling tasks. The screens shown below demonstrate how uncomplicated it can be to make sophisticated Hall and van der Pauw measurements.

This system menu for the Model 926B Differential Hall Profiler makes it easy to begin testing almost immediately. Menu options include a choice of high or low resistivity modes, and room temperature or dual temperature analysis. This menu also lets the user control etching, measurement technique, printing, system diagnostics, and measurement replay. No programming experience is required to set up or operate the system.

The variables menu for the Model 926 system simplifies setting measurement parameters such as number of cycles, etch and delay times, sample current, Hall scattering factor, sample thickness, magnetic field, Hall voltage filtering, and maximum auto-etch time. Default parameters suitable for many devices are supplied for each parameter, and can be easily modified for a particular application.

The Model 925/926 systems automatically take all needed measurements, perform the appropriate data reductions, and present the output in a straightforward, easy-to-interpret tabular format.

The 926 systems perform all the operations required for differential Hall measurements. There's no need for the user to perform data reduction or additional calculations. The system can even produce camera-ready plots like this graph of mobility and carrier concentration vs. depth to simplify the publication of a study's results.



Specifications

The 925 and 926 systems are based on many of the components of the Model 80 Package, and also include the connections to the sample via a 925-EBC-1 sample holder, an Oxford Instruments magnet, and all necessary wiring, gas and liquid handling equipment to make Hall Effect measurements. These specifications indicate the overall level of performance for the complete system. For more detail or for specifications for individual components of the system, refer to the system's user manuals.

SAMPLE RESISTANCE: From <1mΩ to many GΩ. "LOW-RES" mode is used for low resistances, "HI-RES" mode for high resistances (>100kΩ).

SHEET RESISTANCE: From <1mΩ to >10GΩ. Repeatable within 1% relative standard deviation.

VOLTAGE NOISE: Standard deviation of a set of voltage data points from the sample is <40nV using a copper source under 1Ω resistance. Each data point is an average of ten Model 196 voltage readings.

INPUT CURRENT: <1pA with properly cleaned sample holder (HI-RES mode).

INPUT RESISTANCE: >1TΩ with properly cleaned sample holder (HI-RES mode).

TEST CURRENT: LOW-RES: 1nA to 100mA, HI-RES: 100pA to 100mA

COMPLIANCE VOLTAGE: +8V

ELECTROMAGNET: Up to 0.35T without cooling water, up to 0.4T continuous operation with cooling water.

0.5% homogeneity using 38mm planar poles

Software controls field polarity.

SAMPLE SIZE: Up to 9mm × 9mm.

LIQUID NITROGEN: Dewars hold 0.3 liters of liquid nitrogen. Refill required no more than once every 2.5 hours under normal laboratory and experimental conditions.

ACCESSORIES INCLUDED

- Complete assembled hardware cabinet with all equipment except the computer installed and tested.
- Complete operating software package with "run-time" key (925-SOFT or 926-SOFT) ready to install on your computer.
- One EBC-1 sample holder installed in the system and a package of 10 replacement holders.
- IEEE-488 cable for connecting the computer to the measurement system.
- IEEE-488 interface card for the computer.

OPTIONAL ACCESSORIES

HARDWARE:

925-BC	Package of 10 EBC-1 sample holders.
925-HS	Hall sensor mounted on sample holder. Used to verify system operation and to calibrate magnetic field.
7007-1	Shielded IEEE-488 cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 cable, 2m (6.5 ft.)

CONTROLLER:

925-CC	COMPAQ 286 controller. When purchased with the system, the IEEE-488 interface card and 92X-SOFT operating software are installed and tested prior to shipment.

SOFTWARE:

925-SOFT	Extra set of operating software and "run-time" key for 925A or 925B.
926-SOFT	Extra set of operating software and "run-time" key for 926A or 926B.
925-SOURCE	Source code and operating software for 925A and 925B.
926-SOURCE	Source code and operating software for 926A and 926B.
500-ASYST1234	ASYST Software Package. Required to modify 925 or 926 operating software.

ORDERING INFORMATION

925A
Room Temperature Hall System

925B
Dual Temperature Hall System

926A
Room Temperature Differential Hall Profiler

926B
Dual Temperature Differential Hall Profiler

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

OPTIONAL EQUIPMENT NOT SUPPLIED BY KEITHLEY

Computer: The software supports IBM AT, Compaq 286, and Compaq 386 computers. The computer must be equipped with VGA graphics (color, not monochrome), and a math coprocessor. Memory capacity of 640kB is required, as well as a 20MB hard disk.

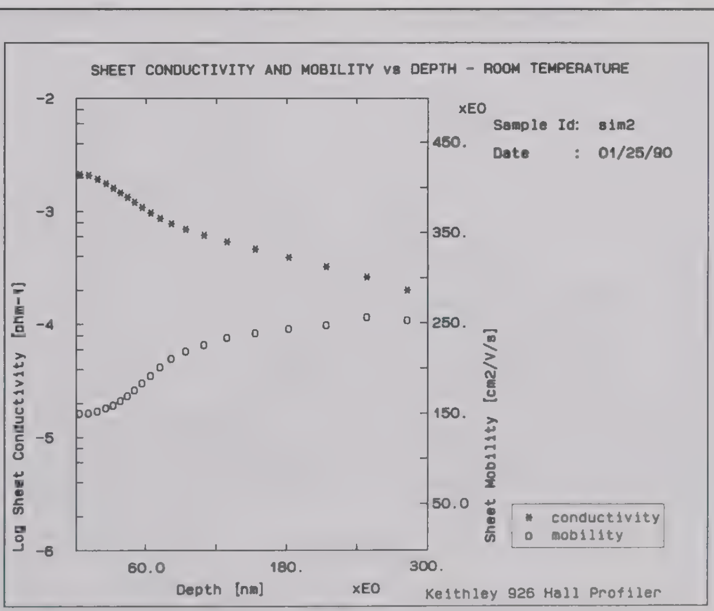
Printer: The software supports the Epson FX850.

Plotter: The software supports the HP7475, 7440, 7470 or Roland DXY-1200, using either the IEEE-488 or RS-232 bus.

CONSUMABLE SUPPLIES REQUIRED	925A	925B	926A	926B
Liquid nitrogen		•		•
Dry nitrogen or air*			•	•
De-ionized water and weak acid or alkaline solutions**				

* Needed to dry the sample. Should be supplied by a low-pressure gas regulator. Tubing is supplied to connect the regulator to the system.

** Needed to etch the sample. Specific formulas for mixing these solutions are included in the system manuals.



220/617 High Impedance Hall Effect System

ORDERING INFORMATION

220
Programmable Current Source (see page 146 for complete specifications)

617
Programmable Electrometer/Source (see page 53 for complete specifications)

These products are available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

196	System DMM (see page 27 for complete specifications)
199	System DMM/Scanner (see page 24 for complete specifications)
7024-3	Triax Cable, 0.9m (3 ft.) (3 required)
7025-10	Low Noise Triax Input Cable, 3m (10 ft.)

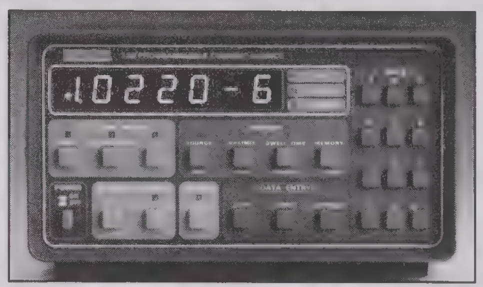
See page 163 for descriptions of all accessories.

Alternative economical approaches to Hall coefficient and resistivity measurements

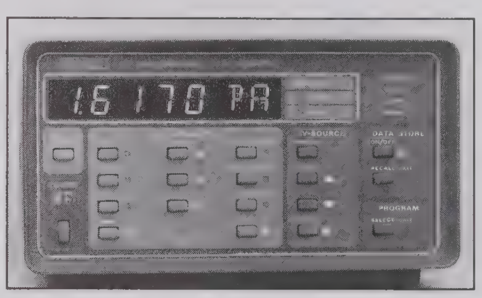
Occasionally, when working with samples with very high resistivity, semi-insulating GaAs, and similar materials with resistivities above $10^8\Omega$, alternative system configurations may be able to produce more reliable data than standard, pre-configured Hall Effect systems. Such systems demand careful shielding and guarding, and typically include a current source, two electrometer buffers and an isolated voltmeter. The schematic shows a suggested configuration for these high resistivity applications.

The range of the system shown here is very wide. The high resistance end is limited by the minimum output of the current source. A current of 100pA can be supplied with an accuracy of about 2%. If the resistance of each leg of the sample is no more than 1TΩ, the maximum voltage developed will be 100V, within the range of the Model 220 current source and the Model 617 electrometers. This system will provide good results with samples as low as 1Ω per leg, if a test current level of 100mA is acceptable. Even at 100mΩ per leg, accuracy is approximately 2%.

Leakage currents are the most important sources of error, especially at very high resistances. One important advantage of this circuit is that a guard voltage is available for three of the sample terminals, which virtually eliminates both leakage currents and line capacitance. The fourth terminal is at circuit LO or ground potential and does not need guarding.

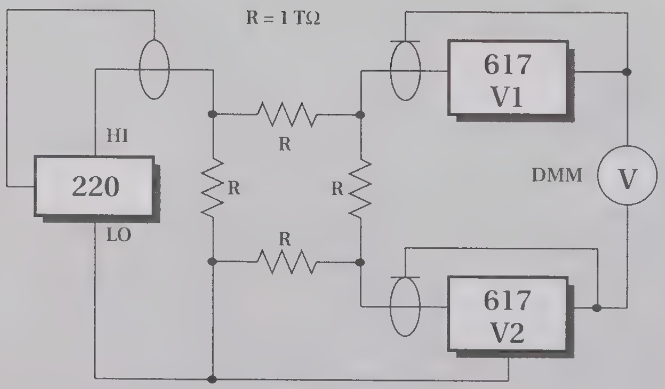


The Model 220 Current Source (page 146) offers material researchers ±0.5pA/step to ±101mA DC output , combined with $10^{14}\Omega$ output resistance.



The Model 617 Electrometer/Source (page 53) provides $10^{14}\Omega$ input resistance and fA input current.

Call Keithley for additional guidance in selecting equipment for specific high resistivity applications.



The suggested equipment configuration (left) was developed for very high resistance van der Pauw or Hall Effect measurements. This measurement system includes a Model 220 current source, two Model 617 electrometers (used as unity-gain buffers) and a Model 196 or Model 199 digital multimeter. The current source is used with a Model 6167 guarded input adapter, which minimizes the time constant of the current source and cable. Three Model 7024-3 triax cables connect the source and the electrometers. A custom cable is needed for the fourth sample terminal, which can be made simply by adding a banana plug to a 7025 triax cable assembly. Two insulated banana leads are used to connect the digital multimeter to the pre-amp outputs for the electrometers. The insulation resistance of the leads and supporting fixtures for the sample should be at least 100 times the leg resistance (R). The entire sample holder must be shielded to avoid electrostatic pickup. If the sample is in a dewar, this should be part of the shield.

Introduction 110

705
20-Channel Scanner Mainframe 112

706
100-Channel Scanner Mainframe 112

707
Switching Matrix Mainframe 114

Switching Cards

Selector Guide 116

Switching Cards for 705 and 706 118–128

Switching Cards for 707 129–137

Scanners and Switches

Introduction

SWITCHING:
Key To System Integrity

Achieving required system accuracies and precision requires selection of appropriate instruments, creativity in designing test methods, and careful attention to specifications and error terms. Most test system designs are complex enough that it is in the designer's best interest to minimize the number of uncontrolled variables. To accomplish this, the system switch performance should be tightly specified.

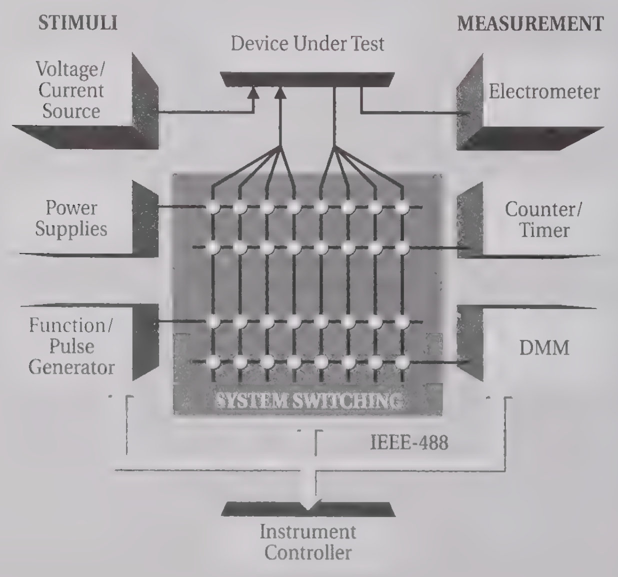
Special consideration should be given to tests which approach the specified limits of accuracy, resolution, or sensitivity of the measurement or sourcing instruments. These generally represent the "most critical test requirements", and switching should be selected to support these tests. A system designed to perform against the "most critical test requirements" will usually satisfy other test requirements as well.

Selecting the Right Switch

Match the system's critical test requirements against the specified performance of the switch. If the requirement is to measure a 1 volt reference to 1 microvolt, be certain that the contact potential of the switch is not hundreds of microvolts. If switching of power supply voltage is required, be certain that the switch has sufficient current carrying capacity. When measuring resistance below 1kΩ, be certain that the switch will support 4-wire measurements.

No switch satisfies all requirements. A variety of different switches matched to test needs may be required. Keithley can help with the broadest range of fully specified switching performance in the industry.

FIGURE 1: General Purpose Test System



Switching Configurations

The variety and size of switching configurations available determine the efficiency of the final switching design including the amount and complexity of cabling and interconnect at the time of system integration. These are the basic building blocks of any switching system.

A switching configuration can be described by the electrical property being switched, its mechanical construction, or function in the test system (**Figure 2**). These descriptions of the signal paths or electrical interconnects are necessary for laying out and wiring the test system.

Matrix Switching. A matrix switch is the most versatile type of system switching. Any input can be connected to any output, singly or in combination. This helps minimize the need for complex wiring and interconnect systems, and can simplify the DUT interface.

Multiplex Switching. A multiplex switch connects one instrument to multiple devices under test, or multiple instruments to one device under test. Example applications include capacitor leakage, connector/switch contact, and insulation resistance test systems. The multiplex switch is useful in combination with matrix or other configurations to expand switching capacity by sharing electrical paths, provide additional isolation and reduce crosstalk between channels, or to build special configurations.

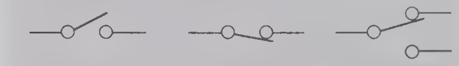
Scanner Switching. A scanner is a special case of multiplex switching in which switch closures are sequential or serial, sometimes with the capability to skip channels. Applications include burn-in testing of components, monitoring time and temperature drift in circuits, and data acquisition of system variables such as temperature, pressure, and flow.

Isolated Switching. The isolated switch configuration consists of individual uncommitted relays, often with multiple poles. Isolated switches are not connected to any other circuit, and are therefore free for building very flexible and unique combinations of input/output configu-

FIGURE 2: Types of Switching Configurations

1. Electrical Property	Voltage Switching	Normally open, path interrupted
	Current Switching	Normally closed, path maintained

2. Mechanical Construction



Form A: SPNO	Form B: SPNC	Form C: SPDT
(Single Pole Normally Open)	(Single Pole Normally Closed)	(Single Pole Double Throw)

3. Function

Scanner	Sequential switching of multiple inputs to one output
Multiplexer	Random switching of one input to multiple outputs
Actuator	Random access, independent isolated relays (one input to one output)
Matrix	Random access switching of multiple inputs (rows) to multiple outputs (columns)

ration with the addition of some external wiring. This type of switch can be useful for creating additional isolation between circuits, providing safety interlock, actuating other relays or circuits, or building special topologies such as binary ladders and tree structures.

Electrical Specifications

Electrical specifications of the switching cards contribute significantly to the overall performance and signal integrity in the test system. When trying to achieve high accuracy, resolution, sensitivity or route high frequency signals, high currents and voltages with minimum degradation in the test signal, the electrical performance of the switch card must be known.

The switching card specifications represent the performance of a single card. If additional cards are connected together, actual performance parameters such as offset current and insertion loss will be a function of the entire system, not just a single card. Each extra card and connecting cable adds some degradation. It may be necessary to characterize the complete system (including switching) in some applications.

Figure 3 describes a few performance characteristics and where they apply to improve system performance. There are many other characteristics to consider depending on the type and level of signal being switched and the expected performance from the test system.

FIGURE 3: Switching Performance Characteristics

Characteristic	Necessary For:
Contact Potential	Precision measurement of voltage signals below 1V, as in reference testing, drift testing, and temperature coefficient testing
Current Offset	Measurement of signals below 1mA, as in semiconductor characterization and insulation resistance tests
Characteristic Impedance	Signal integrity in RF switching
Thermocouple Reference	Accurate measurement of thermocouple sensor devices
Four Wire	Precision measurement of resistances below 1kΩ and switching of remote sensing voltage supplies
Maximum Current	Switching of power supplies and high power circuits
Maximum Voltage	Isolation and safety in high voltage systems

A more thorough discussion of switching specifications and their effect on measurement performance can be found in Keithley's Switching Handbook. Call **1-800-552-1115** or your local sales office to qualify for your personal copy.

Mainframe Capabilities

The switching mainframe provides a convenient mechanical and programming environment for your Keithley switching cards, and can be selected to suit the size of the system. Models 705 (two-slot) and 706 (ten-slot) Scanner mainframes are compatible with the full range of 26 different 705x, 706x, 715x, and 716x series switching cards. These mainframes are suitable for experimental systems, engineering workstations, and medium scale ATE, and will control up to 1000 relays in various configurations.

The Model 707 mainframe supports both matrix and multiplex configurations, and accepts up to six switching cards in any combination from the 707x series. This mainframe will control up to 2880 relays for large ATE system applications. Certain switching cards are specially designed for low-level semiconductor applications.

KEITHLEY SWITCHING MAINFRAMES

MODEL	DESCRIPTION	PAGE
705	Scanner Mainframe (2-slot)	112
706	Scanner Mainframe (10-slot)	112
707	Switching Matrix Mainframe (6-slot)	114
740	System Scanning Thermometer	43
199/1992	System DMM/Scanner with 8-Channel Scanner Option	26

System Expansion

Expansion can be easily accomplished with any of Keithley's mainframes using Master/Slave operation. In this mode, up to four additional slave mainframes (of the same type) may be controlled by one master and programmed from one IEEE-488 address as a single unit.

Memory. Each switching mainframe has built-in memory to save and recall relay setups. This non-volatile memory retains setups even through power loss, and helps reduce programming and improve system throughput.

Relay Status. Programmed state of each relay can be determined quickly and easily by using the Inspect Mode (Program 93, Model 706) or by visually scanning the display on the Model 707. This information is also available over the bus with a simple input command.

Digital I/O is built-in for your convenience. TTL-compatible inputs and outputs can be programmed through the IEEE-488 interface to monitor status, interrupt on state changes, or control external logic circuits and devices. It is available at the rear panel on a separate connector, so there's no need to use one of the system card slots.

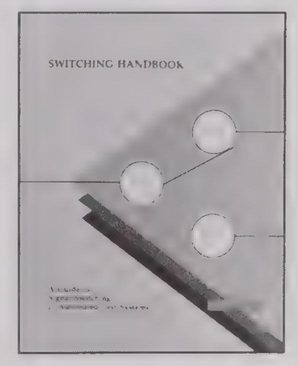
Programming of Keithley switching mainframes allows for several different operating modes, trigger sources, and delays to unburden your IEEE-488 controller or PC for better task management and data handling. The instrument can be set to:

- Scan a range of channels at programmed intervals.
- Advance to the next setup based upon input trigger.
- Randomly close or open multiple relays.
- Issue a "Ready" signal to a measurement instrument.

...and much more.

Application Assistance

Call our experienced application engineers at **1-800-552-1115** (U.S. only) with your system requirements and let us assist in developing the right switching solution for your need. Ask for your personal copy of Keithley's Switching Handbook.



Scanners

MODEL 705

- **2 switching card capacity**
- **Economy**
- **Bench and small systems**
- **40 channels/mainframe**

MODEL 706

- **10 switching card capacity**
- **Expandable to 1000 channels**
- **Large system applications**
- **Memory stores 75 configurations**
- **Inspect mode displays relay status**

IEEE-488

[illegible]

705
2-Slot Scanner Mainframe

705/7065
2-Slot Scanner Mainframe with Hall Effect Card

706
10-Slot Scanner Mainframe

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

[illegible]

CABLES, ADAPTERS

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

RACK MOUNT KITS (705)

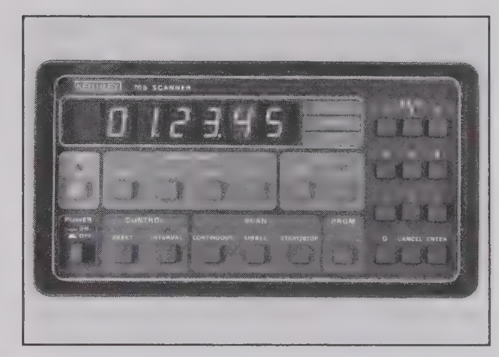
1019A-1	Single Fixed Rack Mount Kit
1019A-2	Dual Fixed Rack Mount Kit
1019S-1	Single Slide Rack Mount Kit
1019S-2	Dual Slide Rack Mount Kit

RACK MOUNT KITS (706)

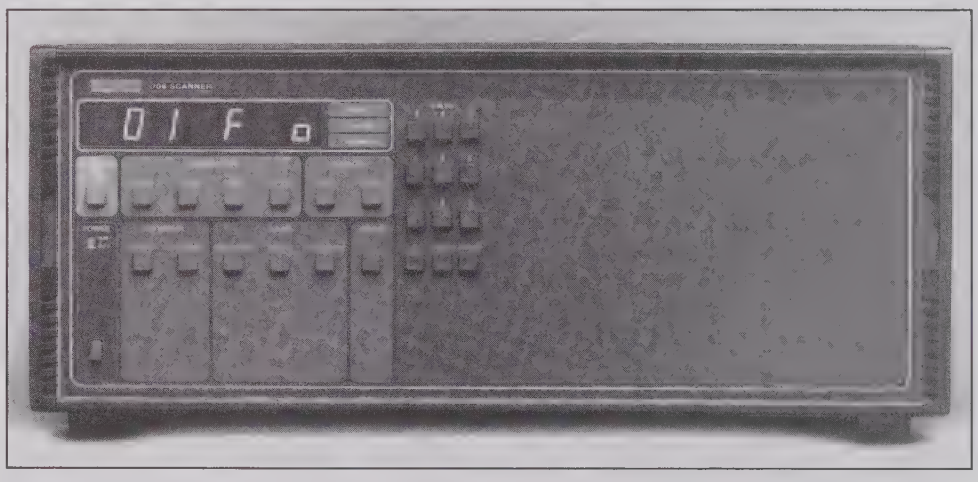
7068	Fixed Rack Mount Kit
7069	Slide Rack Mount Kit

See page 163 for descriptions of all accessories.

The Model 705 has capacity for two switching cards, allowing up to 40 channels of 1-pole switching (expandable to 200 channels). A built-in day/time clock, IEEE-488 interface, and direct front panel control make the 705 ideal for bench or workstation measurements.



The Model 706 has capacity for 10 switching cards, allowing up to 200 channels of 1-pole switching or 200 matrix crosspoints. The matrix memory stores up to 75 sets of complex relay closures, and recalls any one by selecting the memory location or in sequence through the step scan control. A digital I/O port with 8 lines out is convenient for monitoring or controlling some external system parameters.



The available switching cards and slot capacity of the Models 705 and 706 Scanners allow your system to be optimized for economy, measurement precision, future expansion, sensitivity, or a number of other criteria. Regardless of the need, the solution can be found in Keithley's line of switching products.

Switching Cards

Select from over 26 switching cards for the 705 and 706 with signal handling capabilities that include:

- Voltage switching, 30nV to 1300V
- Current switching, 10fA to 5A
- RF switching, 500MHz
- Thermocouple switching with precision temperature reference
- 1-, 2-, 3-, and 4-pole switches
- Matrix, scanner, multiplexer, actuator
- Dry reed or mercury wetted contacts

There is no reason to compromise your system's performance—simply select the switch to suit the application.

System Expansion

Model 705 or 706 scanner mainframes can be expanded by adding up to 4 mainframes in a Master/Slave configuration. This simplifies programming and uses only one IEEE-488 address.

System Control

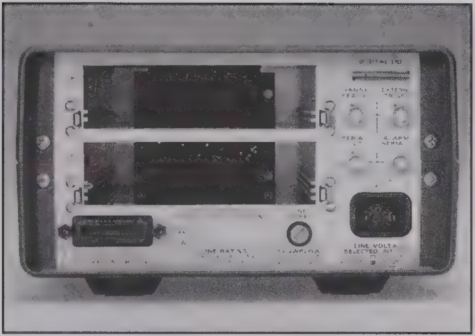
Each scanner mainframe includes an IEEE-488 interface port for simple and direct computer control. All front panel capabilities are available over the bus, as well as status, service request interrupts, control, and readback from the built-in digital I/O.

The TTL-compatible EXTERNAL TRIGGER steps the mainframe to the next channel in sequence. CHANNEL READY provides a pulse output to other instruments at the completion of the programmed settling time.

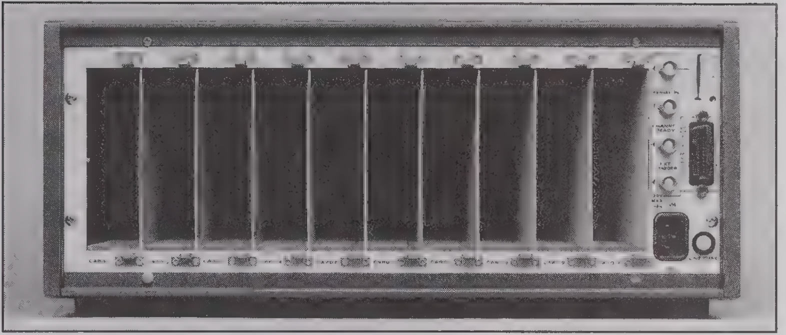
Switching Modes

Operation of the scanner mainframes can be set to 1-pole, 2-pole, 4-pole, or matrix programming depending on the switching cards selected.

Scanning can be set to sequence between programmed First and Last channels in a step, sweep, or continuous manner. The interval



705 rear panel



706 rear panel

between channels is programmable in single or continuous scanning modes. The interval between channels in the step mode is determined by the trigger signal.

Random access switch closures can be programmed by simply entering the channel number to be closed. Any number of channels may be closed at one time; this is particularly important for matrix operation.

Setup Memory

The memory in a Keithley scanner mainframe can Store and Recall sets of relay configurations. Using the memory minimizes bus transfers by permitting a series of relay setups to be down loaded to the instrument's memory. Then any setup can be recalled by calling up the memory location. Five memory locations are available in the Model 705, and 75 non-volatile locations are in the Model 706 (setups are retained through power down).

An Inspect capability in the Model 706 allows the examination of all relay closures in any memory location. This status can also be read back over the IEEE-488 bus.

CAPACITY:
705: Two plug-in cards per mainframe.
706: Ten plug-in cards per mainframe.

EXPANSION CAPACITY: Daisy chain allows up to 4 slave units with 1 master unit.

SWITCHING RATE: 100 channels/second (10ms), programmable to 1 channel/16 minutes (999.999 seconds).

RELAY DRIVE:
705: 350mA minimum.
706: 4A minimum.

CARD SIZE: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.).

[illegible]

0	**Digital I/O**	Read or change state on digital I/O port.
1*	**Date Format**	Changes date display between MM.DD and DD.MM.
2*	**Settle Time**	Time to output CHANNEL READY pulse after closing relay.
3*	**IEEE Address**	Set bus address; cannot be programmed from bus.
4*	**Save Setup**	Stores present relay setup in numbered buffer.
5*	**Restore Setup**	Recalls relay setup.
6*	**Poles**	1-, 2-, or 4-pole configuration for scanning (1-pole requires 7056). 0-pole for matrixing.
7	**Alarm Time**	Set time for Alarm output pulse; repeats daily.
8	**Self Test**	Check RAM, ROM, LEDs.
90*	**Stand Alone**	Single configuration.
91*	**Master**	Daisy chain configuration.
92*	**Slave**	Daisy chain configuration.
93*	**Inspect**	Preview of relays to be closed (706 only).
94*	**Clear**	Clear buffer location (706 only).
99	**Reset**	Reset battery backup parameters to factory values.

*Battery back-up.

[illegible]

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Display Mode, Output Format, EOI, SRQ, First, Last, Open, Close, Display Channel, Alternate Output, Pole Mode, Date Format, Save/Restore, Reset, I/O Port, Date, Settling Time, Interval Time, Alarm Time, Program Mode, Trigger Mode, Terminator, Self Test.

DIGITAL I/O PORT: A separate I/O port consisting of eight input and eight output lines as well as common (IEEE-488) and +5VDC. Outputs will drive one TTL load. Inputs represent one TTL load. Mating connector supplied.

[illegible]

DISPLAY: Seven 0.5 in. LED digits with decimal point, function, and IEEE status annunciators.

INTERNAL CLOCK: Displays hour/minute/second or date/month; <1 minute/month error (typical).

BATTERY BACKUP: Rechargeable 3.6V NiCd. 1 month retention of data with unit turned off.

OPERATING ENVIRONMENT: 0°–50°C, 0%–80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: –25° to 65°C.

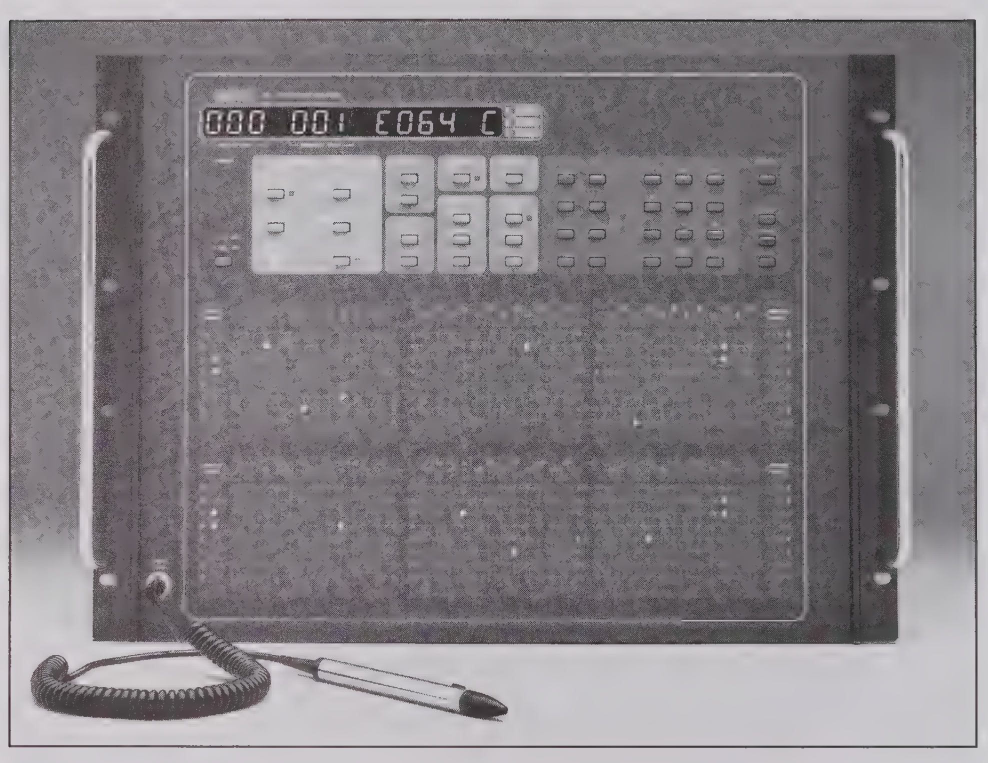
CONNECTORS: Four BNC: External Trigger, Alarm Out/Serial In, Channel Ready, Serial Out (TTL compatible).

DIMENSIONS, WEIGHT:
705: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14½ in.). Net weight 3kg (6½ lbs.).
706: 178mm high × 438mm wide × 448mm deep (7 in. × 17¼ in. × 7⅝ in.). Net weight 8.6kg (19 lbs.).

707 Switching Matrix

- Variety of matrix and multiplexer cards to match your signals
- Expand in groups of 12 to 360 columns (2880 matrix crosspoints)
- Saves system integration and test program development time
- Analog backplane for automatic switching card interconnect
- 100 setup non-volatile matrix memory

IEEE-488



ORDERING INFORMATION

707
6-Slot Switching Matrix with instruction manual, power line cord, relay test connector, fixed rack mounting hardware

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

The Model 707 Switching Matrix will save you time and money in designing, integrating, verifying, and maintaining your test system and test software. The matrix configuration provides maximum flexibility in signal switching and makes configuring a system easier, allowing multiple input pins to be connected to any others through simple paths. Wiring and interconnects are simplified to save labor during system integration, and provide easier access for maintenance. Test program development can be interactive with continuous display of crosspoint status to verify setups.

BACKPLANE CONNECTION

Card Family	Model	Config.	General Purpose	Semiconductor	High Frequency
Universal	7070	96 open collector drivers	•	•	•
General Purpose	7071	8×12 matrix	38-pin termination block		
General Purpose	7071-4	Dual 4×12 matrix	38-pin termination block		
Semiconductor	7072	8×12		Triax	
Semiconductor	7072-HV	8×12		Triax	
Coaxial	7073	8×12			BNC
General Purpose	7074-D	Eight 1×12 multiplexer	75-pin termination block		
General Purpose	7074-M	Eight 1×12 multiplexer	75-pin termination block		
General Purpose	7075	Eight 1×12 multiplexer	25-pin D subminiature		
General Purpose	7076	Dual 4×12 matrix	25-pin D subminiature		

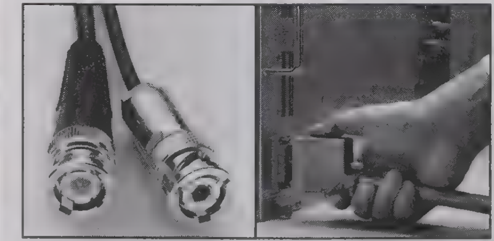
Analog Backplanes

Three separate analog backplanes automatically make row connections between cards of a given family. Separating the analog backplanes permits designing each to maintain the performance characteristics within a card family when multiple card types are mixed within a mainframe.

Within a mainframe, matrix cards are connected along the rows via the analog backplanes. This reduces the need for complex harnesses and external wiring while saving time in design and system integration.

Quick Connect/Disconnect

Cabling and interconnect to instrumentation and DUT pins are also simplified through the use of standard connector types which can be easily connected and disconnected for system assembly and maintenance. Cable accessories are available in either finished assembly or kit form.



Switching Matrix 707

Interactive "One Touch" Programming

The optional Light Pen operates on the setup memory or directly on the relay states, making test development easy. Simply point the light pen to the display crosspoint and press the button. The front panel provides instant visual feedback of the change for verification and displays continuous status for monitoring setups or debugging tests.

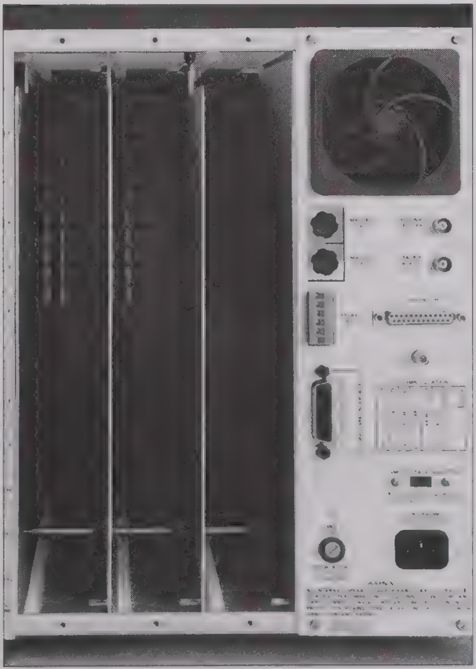
A 100 setup non-volatile memory stores programmed matrix configurations for recall or to upload to a computer file at the end of test development. Stored computer files can be read back into the 707 setup memory to change test sequences or devices.

Throughput and System Capability

Matrix setups can be recalled from memory at rates up to 200 setups per second using one of several hardware or software trigger conditions. When a trigger is received, the Model 707 will step sequence to the next location in the internal setup memory. An output Trigger with programmable delay time is useful for synchronizing with other instruments in the system. Hardware triggers can be programmed for either positive or negative edges.

Simplified Maintenance

Access for maintenance is made easier by the quick disconnect cable terminations. Once these cables are disconnected a relay card can be removed and a Model 7070 Universal Adapter Card installed in its place. This card extends the relay card and provides access to all of the analog and digital backplanes for troubleshooting.



OVERVIEW

CAPACITY: Six plug-in cards per mainframe.

EXPANSION CAPACITY: Daisy-chain expansion of up to four Slave units with one Master unit.

ANALOG BACKPLANES: Backplanes provide automatic row expansion between similar relay cards within one mainframe.

DISPLAY: 14-segment alphanumeric LED display, plus individual status LEDs.

MEMORY: Storage for 100 matrix setups, lithium battery backup.

PROGRAMMED SETTLING TIME: 0 to 65 seconds in 1ms increments.

FRONT PANEL MENU: Digital I/O; External Trigger edge; Matrix Ready level; Master/Slave operation; IEEE-488 address; Relay Settling Time; Self Test; Card Identify; factory defaults.

TRIGGER SOURCES: External Trigger (TTL compatible, programmable edge, 600ns minimum pulse width); IEEE-488 bus (TALK, GET, "X"); manual.

STATUS OUTPUT: Matrix Ready (TTL compatible, programmable high- or low-true): goes false when relays are switched, true at end of Programmed Settling Time.

MAKE-BEFORE-BREAK, BREAK-BEFORE-MAKE: Programmable by row.

LIGHT PEN OPTION: Controls crosspoints, memories, make-before-break and break-before-make. One light pen controls Master and all Slaves.

CARD SIZE: 52mm high × 347mm wide × 523mm long (2 in. × 13.6 in. × 20.6 in.).

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters programmable except for IEEE-488 bus address and Master/Slave operating mode.

EXECUTION SPEED

MAXIMUM TRIGGER RATE: 200 setups per second (stepping through previously stored setups with make-before-break and break-before-make disabled).

TRIGGER RESPONSE TIME:
External Trigger: <1ms.
IEEE-488 GET: <1ms.

RESPONSE TO IEEE-488 COMMAND (to close a single relay, excluding relay settling time):
Stand Alone: <15ms.
Master and Four Slaves: <55ms.

DOWNLOAD TIME (one setup to 707):
Stand Alone: 50ms typical.

GENERAL

DIGITAL I/O (TTL compatible):
Data: 8 inputs, 8 outputs.
Control: Input Latch, Output Strobe, Matrix Ready.

REAR PANEL CONNECTORS:
Two BNC: External Trigger, Matrix Ready.
One DB-25: Digital I/O.
Two 8-pin DIN: Master/Slave In, Master/Slave Out.
One 6-pin screw terminal plug: Relay Test.

ENVIRONMENT:
Operating: 0° to 50°C. **Storage:** –25 to 65°C.

POWER: 90–125V AC or 180–250V AC (internally/externally selected), 50–60Hz, 140VA maximum.

RELAY DRIVE: 2.9A minimum.

DIMENSIONS, WEIGHT: 356mm high × 432mm wide × 574mm deep (14 in. × 17 in. × 22.6 in.). Net weight without cards 18.2kg (40 lbs.).

ACCESSORIES AVAILABLE

7078-PEN:	Programming Light Pen (includes holder)
CABLES, ADAPTERS	
7007-1:	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2:	Shielded IEEE-488 Cable, 2m (6.6 ft.)
7051-2:	BNC to BNC Cable, 0.6m (2 ft.)
7051-5:	BNC to BNC Cable, 1.5m (5 ft.)
7078-DIN:	8-Pin DIN Cable (Master/Slave), 1.8m (6 ft.)
RACK MOUNT KIT	
7079:	Slide Rack Mount Kit

See page 163 for descriptions of all accessories.

Selector Guide

Card Type	Signal Type	Model (Page)	Host System	Contact Configuration	Maximum Switching Levels			Contact Potential	Maximum Recom'd Frequency	Comments	Common Applications
					Volts	Current	Power				
Switch	General Purpose	7066 (p. 123)	705/706	10 channels, 2 Form A	350V	2A	125VA	<30μV	3MHz	Can be jumpered for 10 channels, 2 Form B or 5 channels, 2 Form C and other configurations.	Switching sources and supplies, switching loads, controlling external circuits and devices.
		7156-D (p. 125)	705/706	10 channels, 1 Form A	150V	500mA	10VA	<100μV	3MHz	Economy, dry reed relay. Quick connect. Switch or scan with jumpers.	
		7156-M (p. 125)	705/706	10 channels, 1 Form A	150V	750mA	30VA	<100μV	3MHz	Bounceless, mercury wetted relay contacts. High switching density. Quick connect. Switch or scan with jumpers.	Switching inductive or capacitive loads, high volume testing.
		7166 (p. 127)	705/706	10 channels, 2 Form A	300V	750mA	30VA	75μV typ.	3MHz	Switch or scan w/jumpers. 2A DC or rms carry current, long contact life, low & stable contact resistance.	
		7169 (p. 128)	705/706	20 channels, 1 Form C	500V	500mA rms	10VA	<30μV	2MHz	Can be jumpered to interconnect channels or change from switch to matrix configuration.	Printed circuit board insulation resistance measurements. Coupon testing.
Scanner or Multiplexer	General Purpose	7056 (p. 119)	705/706	10 channels, 2 Form A	150V	250mA	10VA	<100μV	10MHz	Can use as 20 channels, 1 Form A	Solution for general multiplexing applications.
		7156-D (p. 125)	705/706	10 channels, 2 Form A or 20 channels, 1 Form A	150V	500mA	10VA	<100μV	3MHz	Economy, dry reed relay. High switching density. Quick connect. Switch or scan with jumpers.	Materials testing. Electronic component & circuit testing.
		7156-M (p. 125)	705/706	10 channels, 2 Form A or 20 channels, 1 Form A	150V	750mA	30VA	<100μV	3MHz	Bounceless, mercury wetted relay contacts. High switching density. Quick connect. Switch or scan with jumpers.	Materials testing. Electronic component & circuit testing. Power cycling.
		7166 (p. 127)	705/706	10 channels, 2 Form A	300V	750mA	30VA	75μV typ.	3MHz	Switch or scan w/jumpers. 2A DC or rms carry current, long contact life, low & stable contact resistance.	High current sourcing. 2-wire resistance measurements.
		7164-D (p. 126)	705/706	20 channels, 2 Form A	100V	500mA	10VA	<50μV	3MHz	Mass termination, close only 1 channel at a time.	Low cost scanning of many DUTs.
		7164-M (p. 126)	705/706	20 channels, 2 Form A	100V	750mA	30VA	<75μV	3MHz	Mass termination, close only 1 channel at a time, mercury wetted relays.	High volume scanning of many DUTs.
		7074-D (p. 135)	707	8 banks of 12 channels, 3 Form A	200V	500mA	10VA	<5μV	5MHz	Jumpers configure for 1×96, dual 1×48, etc. Dry reed relays.	Temperature coefficient testing. Reference, drift, stability testing.
		7074-M (p. 135)	707	8 banks of 12 channels, 3 Form A	200V	750mA	10VA	<10μV	5MHz	Jumpers configure for 1×96, dual 1×48, etc. Mercury wetted relays.	Burn in testing. Power cycling. Switching logic levels.
		7075 (p. 136)	707	8 banks of 12 channels, 2 Form A	110V	1A	30VA	<5μV	30MHz	Jumpers configure for 1×96, dual 1×48, etc. Mechanical relays switched as high and guard.	Circuit board testing. Electronic component testing. Semiconductor testing.
	Low Voltage	7059 (p. 121)	705/706	10 channels, 2 Form A	200V	100mA	2VA	<1μV	3MHz	Submicrovolt performance w/200V stand-off voltage.	Temperature coefficient testing, reference testing, drift testing.
		7064 (p. 122)	705/706	20 channels, 2 Form A	40V	100mA	2VA	<1μV	10MHz	Close only one channel at a time.	
		7168 (p. 127)	705/706	8 channels, 2 Form A	10V	50mA	—	<30nV	1kHz	Nanovoltmeter switching with JFETs.	Thermocouple testing, low resistance testing.
	High Voltage	7054 (p. 119)	705/706	10 channels, 1 Form A	1000V	500mA	10VA	—	1MHz, 10^7V•Hz	10mA @ 1kV.	Insulation resistance, breakdown testing, power amplifier testing.
		7154 (p. 125)	705/706	10 channels, 2 Form A	1100V	500mA	10VA	<35μV	1MHz	Guards may be common or isolated by channels.	Insulation resistance, component testing, breakdown testing.
	Low Current	7058 (p. 120)	705/706	10 channels, 1 Form C	200V	100mA	—	<250μV	3MHz	<100fA offset current (typical), triax connectors, voltage switching with jumpers removed.	Leakage currents, PCB test coupons, materials research and characterization, semiconductor sub-threshold current.
		7158 (p. 126)	705/706	10 channels, 1 Form C	30V	100mA	—	<200μV	1MHz	<30fA offset current (typical), BNC connectors.	

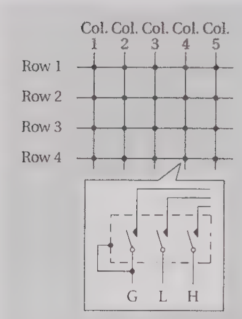
Selector Guide

Card Type	Switch Type	Model (Page)	Mainframe	Card Configuration	Maximum Switching Levels			Contact Potential	Maximum Recom'd Frequency	Comments	Common Applications
					Voltage	Current	Power				
	High Current	7053 (p. 118)	705/706	10 channels, 2 Form C	300V	5A	100VA	<1mV	1MHz	Factory configured for N:1 current multiplexing; remove jumpers for 1:N multiplexing of V signals.	Semiconductor and IC testing, battery and power supply testing.
	Thermocouple	7057A, 7402 (p. 120)	705/706	9 channels + temperature reference, 2 Form A	42V	100mA	2VA	<1µV	—	±0.25°C reference accuracy; –1mV/°C (7057A) or 200µV (7052) reference output.	Thermocouple and mV scanning.
	4-Wire	7067 (p. 123)	705/706	10 ch., *Source* 4 Form *Sense* A	150V 150V	350mA 100mA	10VA 10VA	<50µV <1µV	1MHz 1MHz	—	4-wire (Kelvin) resistance, external sensing of voltage sources, DUT in/out switching.
	RF	7062 (p. 122)	705/706	2 switches/card of 1-pole, 5-throw.	24V	50mA	0.5VA	<20µV	500MHz	50Ω unterminated, only 1 throw of each switch closed at a time, switches can be cascaded.	Communications and digital signals, high speed waveforms, multiplexing of balanced lines.
		7063 (p. 122)	705/706	2 switches/card of 1-pole, 5-throw.	5V	50mA	0.5VA	<20µV	500MHz	50Ω terminated, only 1 throw of each switch closed at a time, switches can be cascaded.	
Matrix	General Purpose	7052 (p. 118)	705/706	5 columns × 4 rows, 3 Form A	200V	200mA	10VA	<5µV	3MHz	Switched high, low, guard.	Differential or Kelvin switching, other complex signal and measurement device switching, multi-pin DUT testing.
		7071 (p. 130)	707	12 columns × 8 rows, 3 Form A	200V	500mA	10VA	<5µV	3MHz	Switched high, low, guard. Quick disconnects for row and column.	
		7071-4 (p. 131)	707	Dual matrix. 4 rows × 12 columns, 3 Form A	200V	500mA	10VA	<5µV	3MHz	Two independent 4×12 matrices, configurable as 4×24. Switched as high, low, and guard.	Circuit board testing. Electronic component testing. Semiconductor test.
		7076 (p. 137)	707	Dual 4 rows × 12 columns, 2 Form A	110V	1A	30VA	<5µV	15MHz	Two independent 4×12 matrices, configurable as 8×24. Switched as high and guard.	Circuit board testing. Electronic component testing. Semiconductor test.
	Semiconductor	7072 (p. 132)	707	12 col.×8 rows: 2 low current rows, 2 Form A	200V	500mA	10VA	<20µV	15MHz	<1pA offset current, $>10^{13}$ Ω isolation resistance.	MOS transistor gate current or quasistatic CV.
				4 gen. purpose rows, 2 Form A	200V	500mA	10VA	<20µV	8MHz	Switched signal and guard.	General source, bias, or measurement signals.
				2 CV rows, 1 Form A	200V	500mA	10VA	<20µV	5MHz	Common guard.	High frequency CV measurement.
		7072-HV (p. 133)	707	12 col.×8 rows: 2 low current high voltage rows, 2 Form A	1300V	500mA	10VA	<50µV	4MHz	<1pA offset current, $>10^{13}$ Ω isolation resistance.	MOS transistor gate current or quasistatic CV.
				4 gen. purpose rows, 2 Form A	200V	500mA	10VA	<20µV	8MHz	Switched signal and guard.	General source, bias, or measurement signals.
				2 CV rows, 1 Form A	200V	500mA	10VA	<20µV	5MHz	Common guard.	High frequency CV measurement.
	Coaxial	7073 (p. 134)	707	12 columns × 8 rows, 1 Form A	200V	1A	30VA	<2µV	30MHz	BNC connectors, unterminated pathways.	Wideband switching of general purpose analog, digital, and low voltage signals.
	Low Current	7152 (p. 124)	705/706	4 rows × 5 columns, 2 Form A	200V	500mA	10VA	<20µV	60MHz	Sub-picoamp offset current. Switched signal, guard. Mass terminated connector.	MOS gate leakage, sub-threshold testing. Insulating properties. Capacitor leakage and dielectric absorption.
		7153 (p. 124)	705/706	4 rows × 5 col., 2 Form A	1300V	500mA	10VA	<50µV	60MHz	1300V switching. <1pA offset.	High voltage device testing.
Special	Hall Effect	7065 (p. 102)	705/706	5 columns × 4 rows, 1 Form A	8V	100mA	—	—	—	Source and measurement switching plus 4 high impedance buffers.	Van der Pauw, Hall bar, and Hall voltage measurements of low or high resistivity samples.
	Universal Adapter	7061 (p. 121)	705/706	—	—	—	—	—	—	7070: Extender cable, card edge connector supplied. 96 open collector drivers.	Troubleshooting extender card, custom relay card.
		7070 (p. 129)	707	—	—	—	—	—	—		
	Prototyping	7070 PCA (p. 129)	707	—	—	—	—	—	—	96 open collector drivers. 117 sq. in. prototype & breadboard area. Extender cables not included.	Unique switching circuits.

7052

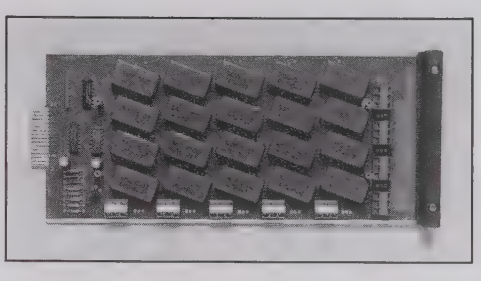
4×5 Matrix Card

- **3-pole Form A**
- **Quick disconnect screw terminals**
- **<5µV contact potential**



Each crosspoint in the matrix consists of a 3-pole Form A (normally open) relay. Shield of each relay is connected to the column GUARD line.

The 7052 is a general purpose switching card. The flexibility of matrix switching allows connection of any row to any column, singly or in combination. Ideal for complex signal and measurement device switching, this matrix card can help minimize your need for custom cables and patch panels because the routings can be customized in software. Switched guards assure high isolation between channels.



MATRIX CONFIGURATION: 4 × 5.

CONTACT CONFIGURATION: 3-pole Form A (High, Low, and Guard).

CONNECTOR TYPE: Quick disconnect screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 15mA per relay typical.

MAXIMUM SIGNAL LEVEL: 200V, 500mA carry/200mA switched, 10VA peak (resistive load).

CONTACT LIFE: 10^8 closures (cold switching); 10^7 closures (at maximum signal levels).

CONTACT RESISTANCE: <1Ω per contact to rated life.

CONTACT POTENTIAL: <5µV per crosspoint (High to Low, <1 minute after actuation).

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}\Omega$ and <5pF.

INPUT ISOLATION:
Differential: $>10^9\Omega$, 50pF typical.
Common Mode: $>10^9\Omega$, 100pF typical.

CROSSTALK: <–60dB @ 1MHz, 50Ω load.

OFFSET CURRENT: <100pA.

COMMON MODE VOLTAGE: 200V peak.

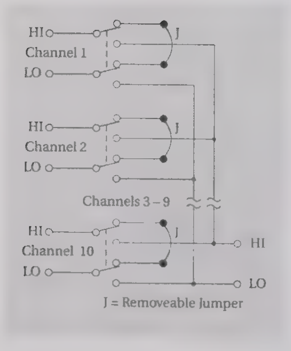
ENVIRONMENT:
Operating: 0° to 50°C, up to 35°C at 70% RH.
Storage: –25°C to 65°C.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

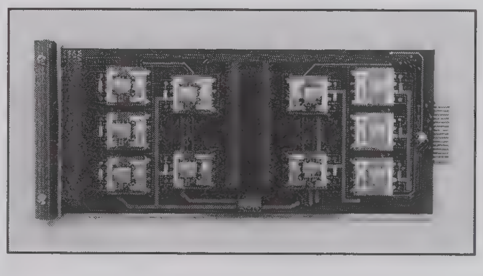
7053

High Current Scanner Card

- **5A switching**
- **10-channel scanner**
- **2-pole Form A**
- **Maintains current path for unselected channel**



The 7053 has 10 channels and features 5A contacts. The switching is designed to maintain current paths for signals not connected to the output, or, when internal jumpers are removed, to provide high input resistance for making voltage measurements. Semiconductor testing, materials research, power supply testing, solar cell measurements, electrochemical applications, and IC testing are among the applications simplified with the 7053 High Current Scanner Card.



CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A with common Guard.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 80mA per relay typical.

MAXIMUM SIGNAL LEVEL: 300V, 5A, 100VA (resistive load only).

CONTACT LIFE: $>10^7$ closures cold switching; $>10^5$ closures at maximum signal levels.

CONTACT RESISTANCE: <0.15Ω to rated life.

CONTACT POTENTIAL: <1mV.

ACTUATION TIME: <15ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9\Omega$, <50pF.

INPUT ISOLATION: $>10^7\Omega$, <150pF.

COMMON MODE VOLTAGE: 300V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25°C to 65°C.

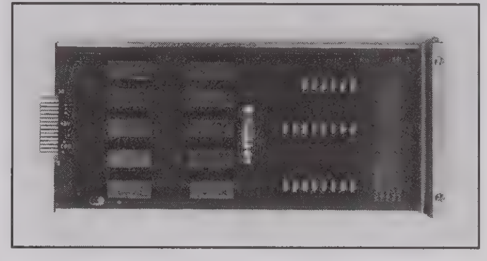
USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

High Voltage Scanner Card

7054

The 7054 is a 10-channel high voltage scanner card. Voltages up to 1000V peak can be switched. LO is common to all channels and the output.

The high voltage switch can be used to selectively source voltages to any of ten circuits or to monitor voltages from as many sources. Applications include insulation resistance, breakdown, capacitor leakage, dielectric absorption, voltage coefficient, voltage stress tests, and monitoring of line voltages, motor voltages, and more.



- **1000V switching**
- **10-channel scanner**
- **1-pole Form A**
- **Screw terminal connections**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: Single pole Form A, common guard connection.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 50mA per relay typical.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

MAXIMUM SIGNAL LEVEL: 1000V, 10mA, 10VA (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

CONTACT RESISTANCE: <1Ω.

ACTUATION TIME: <20ms, exclusive of mainframe.

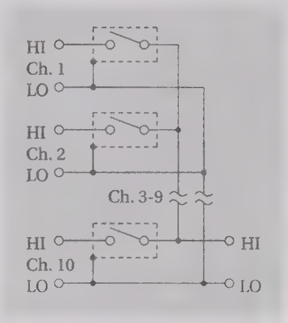
CHANNEL ISOLATION: $>10^{12}\Omega$ and <10pF.

INPUT ISOLATION: $>10^9\Omega$ and <150pF.

GUARD TO CHASSIS VOLTAGE: 200V maximum.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% non-condensing RH.

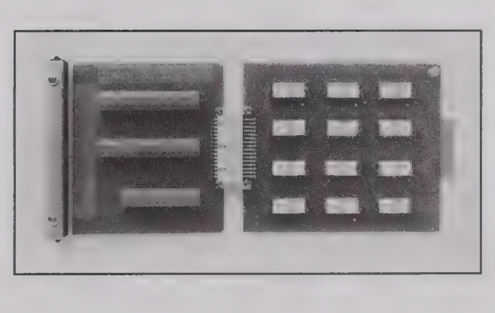
STORAGE ENVIRONMENT: –25°C to 65°C.



General Purpose Scanner Card

7056

The 7056 is a 10-channel scanner card with electrical connection made through the Model 7055 Quick Disconnect supplied. It is a cost-effective and versatile solution to relay switching applications. Each channel of the card has two Form A (SPNO) contacts. The switch may be wired for either 2-pole or 1-pole switching through the selection of the appropriate output. In 1-pole operation, channels HI and LO operate as independent, isolated inputs, thereby effectively doubling the number of input channels.



- **20- or 10-channel scanner configuration**
- **1-pole in 20-channel mode, 2-pole in 10-channel mode**
- **Screw terminal connections on quick disconnect card**

CHANNELS PER CARD: 10 in 2-pole mode, 20 in 1-pole mode.

CONTACT CONFIGURATION: 2-pole Form A; includes Model 7055 Quick Disconnect Card. HI or LO switched to a separate output for 1-pole mode. Common guard connection.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size. Terminals mounted on 7055 Quick Disconnect portion of 7056.

RELAY DRIVE CURRENT: 24mA per relay typical.

MAXIMUM SIGNAL LEVEL: 150V, 250mA, 10VA (resistive load only).

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CONTACT LIFE: $>10^8$ closures cold switching; $>10^7$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <100μV per contact pair input to output with copper leads (<50μV typical).

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9\Omega$, <20pF typical.

INPUT ISOLATION, DIFFERENTIAL: $>10^9\Omega$, <50pF typical.

INPUT ISOLATION, COMMON MODE: $>10^9\Omega$, <150pF typical.

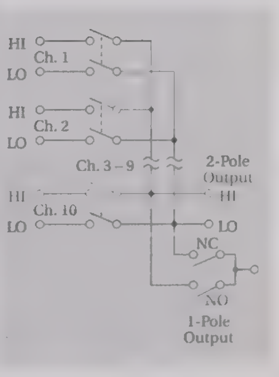
COMMON MODE VOLTAGE: 150V peak.

CHANNEL CROSSTALK: <50dB @ 1MHz into 50Ω load.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25°C to 65°C.

ACCESSORY SUPPLIED: Model 7055 Quick Disconnect.

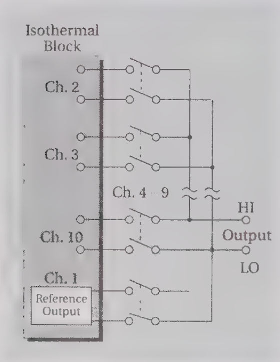


7057A,7402

Thermocouple Scanner Cards

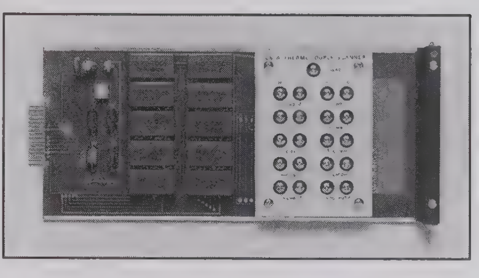
- 9-channel thermocouple scanner
- Cold junction compensated
- 2-pole Form A
- <1μV of switch contact potential

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call:
1-800-552-1115 (U.S. only).



These cards permit monitoring of up to nine thermocouples or other transducers. The nine signal channels use a guarded 2-pole configuration. An isothermal block provides electrical isolation up to 42V while assuring excellent thermal conductivity between cold junction terminations. A sensing device mounted in the isothermal block monitors the cold junction and outputs a calibrated reference voltage which is linearly related to the temperature. The Model 7057A provides a higher change in reference output for improved cold junction sensitivity. Formulae for converting the voltage outputs of all of the most popular thermocouple types are included in the manual. The contact potential of <1μV per channel translates to <0.025°C error for precision measurements on type K thermocouples.

CHANNELS PER CARD: 9 plus temperature reference.
CONTACT CONFIGURATION: 2-pole Form A, with common guard.
CONNECTOR TYPE: Screw terminals in isothermal block, #18 AWG maximum wire size.
RELAY DRIVE CURRENT: 12mA per relay typical.
TEMPERATURE REFERENCE:
7057A: Thermistor in a linearized bridge.
7402: Semiconductor, temperature dependent current source.
TEMPERATURE OFFSET: ±0.05°C maximum from HI to LO of any channel or between any two adjacent channels in one column on the isothermal block. ±0.1°C maximum between any two terminals on the isothermal block. Maximum additional dynamic offset due to 10°C step change in environment: ±0.1°C after one hour settling.

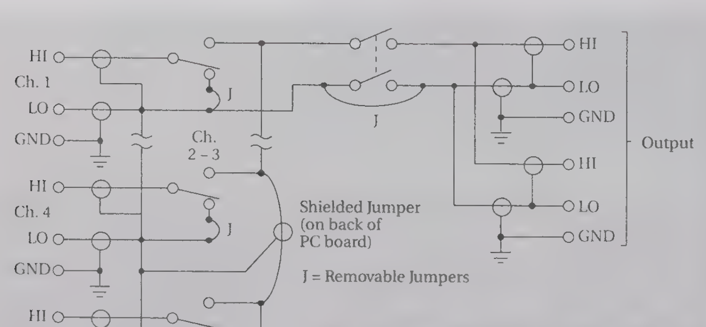


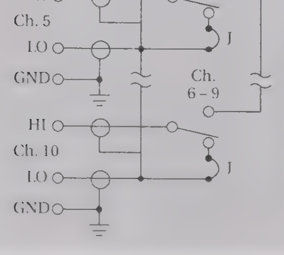
REFERENCE OUTPUT:
7057A: –1mV/°C (0mV at +30°C).
7402: +200μV/°C (+54.63mV at 0°C).
REFERENCE ACCURACY (1 Year): ±0.25°C (10°C to 35°C); ±0.5°C (0°C to 10°C and 35°C to 50°C).
WARM-UP: 1 hour to rated accuracy in mainframe.
MAX. SIGNAL LEVEL: 42V, 100mA, 2VA (resistive load only).
CONTACT POTENTIAL: <1μV.
CONTACT LIFE: >10^8 closures cold switching; >10^6 closures at maximum signal levels.
CONTACT RESISTANCE: <2Ω to rated life.
CHANNEL ISOLATION: >10^8Ω, <10pF.
INPUT ISOLATION: >10^7Ω, <150pF.
COMMON MODE VOLTAGE: 200V peak.
SPECIFIED ENVIRONMENT: 10° to 35°C, up to 70% RH.
OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.
STORAGE ENVIRONMENT: –25° to 65°C.
ACCESSORY AVAILABLE: Model 7401 Type K Thermocouple Wire Kit, 30.5m (100 ft.)

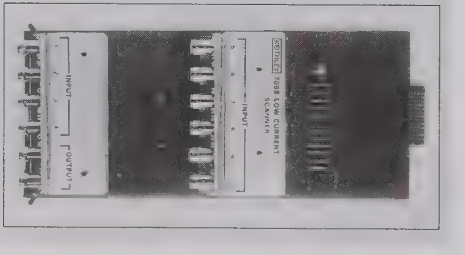
7058

Low Current Scanner Card

- Sub-pA offset current
- 10-channel scanner
- Maintains current path for unselected channel
- Triax connectors







For optimum low level current switching up to 10 channels, the 7058 is designed to introduce minimal offset current error (under 1pA), while guarding ensures that high isolation (10^{15}Ω) is maintained between input HI to input HI.

Removable jumpers allow channels to be configured as voltage switches. Triaxial input connectors provide better shielding and permit direct connection to Keithley electrometers.

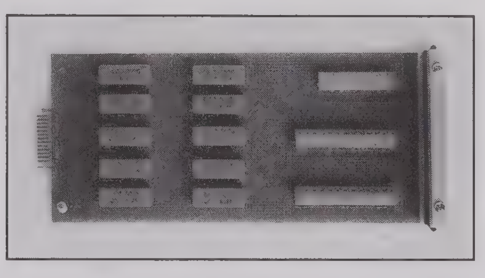
CHANNELS PER CARD: 10.
CONTACT CONFIGURATION: Single pole, break-before-make for signal HI input. Signal LO is common for all 10 channels. When a channel is off, signal HI is connected to signal LO through an internal removable jumper.
CONNECTOR TYPE: Triaxial.
RELAY DRIVE CURRENT: 24mA per relay typical.
MAXIMUM SIGNAL LEVEL: 200V, 100mA (resistive load only).
CONTACT LIFE: >10^7 closures cold switching; >10^6 closures at maximum signal levels.
CONTACT RESISTANCE: <1Ω to rated life.
CONTACT POTENTIAL: <250μV.
ACTUATION TIME: <15ms, exclusive of mainframe.
CHANNEL ISOLATION: >10^{15}Ω, <0.1pF with internal jumper removed.
INPUT ISOLATION: >10^{10}Ω, <50pF (Input HI to Input LO).
OFFSET CURRENT: <10^{-12}A (<10^{-13}A typical).
COMMON MODE VOLTAGE: <100V peak.
OPERATING ENVIRONMENT: 0°–50°C, up to 35°C at 70% RH.
STORAGE ENVIRONMENT: –25°C to 65°C.
ACCESSORY SUPPLIED: 7024-3 Triaxial Cable, 0.9m (3 ft.).

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call:
1-800-552-1115 (U.S. only).

Low Voltage Scanner Card

7059

For low level transducer switching, the 7059 is designed to reduce errors due to thermocouple effects in the contacts (<1μV maximum) and ensure that high isolation ($10^{12}\Omega$) is maintained between input signals. It will switch any one of ten signals to one output, or switch one signal to any one of ten outputs. Switch settling time is less than 2 milliseconds.



- **<1μV contact potential**
- **10-channel, 2-pole scanner**
- **200V switching**
- **Screw terminal connections**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A, common guard connection.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 13mA per relay typical.

MAXIMUM SIGNAL LEVEL: 200V, 100mA, or 2VA (resistive load only).

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <1μV input to output with copper leads (<200nV typical within 1 minute of actuation).

WARM-UP: 1 hour in mainframe for thermal stability.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}\Omega$, <10pF.

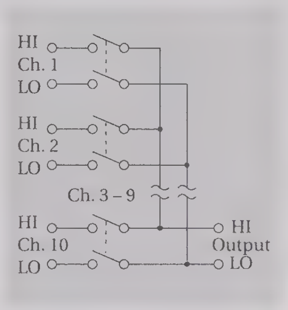
INPUT ISOLATION, DIFFERENTIAL: $>10^9\Omega$, <50pF.

INPUT ISOLATION, COMMON MODE: $>10^9\Omega$, <150pF.

COMMON MODE VOLTAGE: <200V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

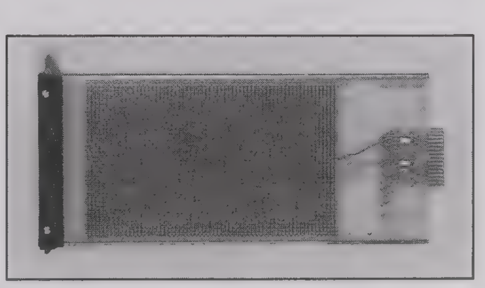
STORAGE ENVIRONMENT: –25°C to 65°C.



Universal Adapter Card

7061

The 7061 was designed with a 6-volt supply, ground trace, and a grid pattern of plated-through holes on 0.1-in. centers for mounting special relays or circuits. Relay drive lines from the scanner mainframe can be used for control. A supplied ribbon cable assembly extends the relay drive lines beyond the enclosure for easy access to relay cards for troubleshooting.



- **Circuit prototyping**
- **Access to relay drive lines**
- **Extender cable**

SUPPLY SPECIFICATIONS: 705 mainframe: 6V, 350mA max.; 706 mainframe: 6V, 4A max.

RELAY DRIVE LINES: 350mA sink.

HARDWARE SPACE: 15/16 in., maximum height a component can protrude from the universal adapter card and fit in the 705 or 706 mainframe.

HOLE SIZE: 0.062 diameter.

HOLE SPACING: 0.1 in. centers

RIBBON CABLE: 2 ft. length with connectors preassembled.

STRAIN RELIEF CLAMP: Assembly provided.

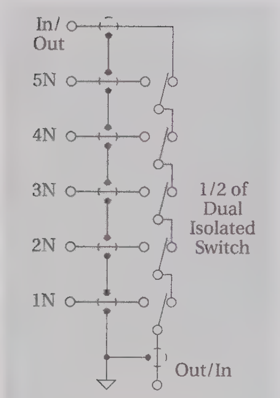
OPERATING CODES: Provided in manual.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

7062,7063

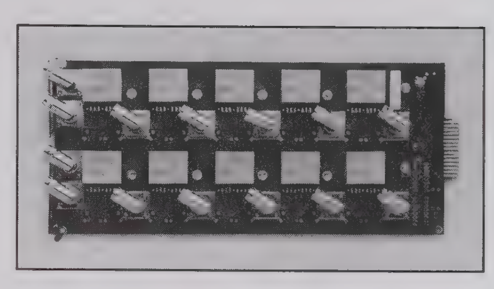
RF Switch Cards

- 500MHz bandwidth
- BNC connectors
- Two independent 1 of 5 switches



Unselected inputs are terminated in 50Ω on Model 7063.

The 7062 and 7063 have two independent 1 of 5 switches. Each switch has a separate through connection which can be used to cascade sections to achieve larger scanning configurations in multiples of 5. The switched transmission line design maintains the 50Ω characteristic through the switch, minimizing reflection and loss. This approach results in reduced capacitance and better frequency response. The 7063 inputs are terminated in the 50Ω characteristic impedance when not selected. A 500MHz bandwidth assures signal integrity over a broad range from DC to communications signals and digital waveforms. Coaxial switching provides additional shielding and noise immunity in the system environment.



USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

SWITCHES PER CARD: 2 (with isolated grounds).

CHANNELS PER SWITCH: 5.

SWITCH CONFIGURATION: 1-pole, 5 throw.

EXPANSION: A through connector is provided for cascading switches.

CONNECTOR TYPE: BNC.

RELAY DRIVE CURRENT: 100mA per relay typical.

ACTUATION TIME: 10ms exclusive of mainframe.

RELEASE TIME: 5ms.

CHARACTERISTIC IMPEDANCE: 50Ω.

TERMINATIONS: 7062: None;. **7063:** 50Ω on unselected inputs.

PROPAGATION DELAY: <2ns.

INSERTION LOSS: <0.1dB below 20MHz, <1.0dB below 250MHz, and <3.0dB below 500MHz.

ISOLATION CHANNEL (switch to channel): >75dB below 20MHz, >55dB below 250MHz, and >60dB below 500MHz.

ISOLATION (switch to switch): >80dB below 20MHz, >70dB below 250MHz, and >60dB below 500MHz.

MAXIMUM SIGNAL LEVEL: 24V on Model 7062, 5V on Model 7063, switched; 50mA; 0.5 watt switched.

CONTACT LIFE: $>10^6$ closures cold switching; $>10^5$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω input to output.

CONTACT POTENTIAL: <20µV.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

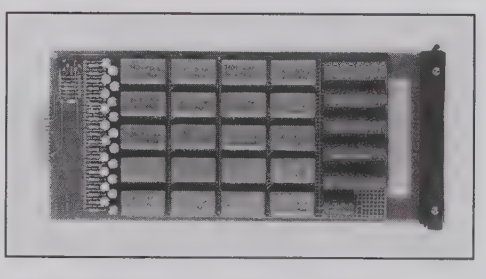
STORAGE ENVIRONMENT: –25°C to 65°C.

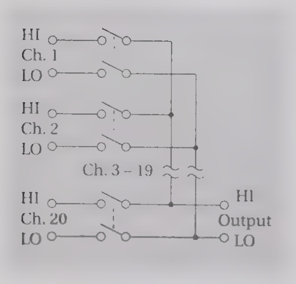
7064

20-Channel Low Voltage Scanner Card

- <1µV contact potential
- 20-channel scanner
- 2-pole Form A relays
- Screw terminal connections

The 7064 has 20 channels and features <1µV thermal offset. It will switch any one of twenty signals to one output, or switch one signal to any one of twenty outputs. Switching is accomplished in less than 2ms. Expected relay life (10^8 closures) is obtained when signals less than 10V or 10mA are switched.





CHANNELS PER CARD: 20.

CONTACT CONFIGURATION: 2-pole Form A, common guard connection.

CONNECTOR TYPE: Screw terminal #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 14mA per relay typical.

MAXIMUM SIGNAL LEVEL: 40V, 100mA, or 2VA (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <1µV differential voltage, input to output with copper leads (<200nV typical within 1 minute of actuation).

WARM-UP: 1 hour in mainframe for thermal stability.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}$, <10pF.

INPUT ISOLATION, DIFFERENTIAL: $>10^9$Ω, <75pF.

INPUT ISOLATION, COMMON MODE: $>10^9$Ω, <150pF.

COMMON MODE VOLTAGE: <100V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

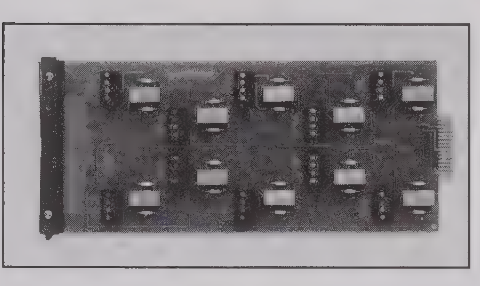
STORAGE ENVIRONMENT: –25°C to 65°C.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

Relay Switch Card

7066

The 7066 is a non-multiplexed switching card with ten independent and isolated channels. Each channel switches 2-pole Form A relays and can be user changed for either Form B or Form C configuration using movable jumpers. The switch specifications are well suited for applications such as power line switching, controlling external circuits and devices, and switching signals where multiplexing is not desired. Each channel is terminated with a screw terminal block which "quick disconnects" from the card.



- **10 isolated switches**
- **2-pole Form A relays**
- **<30µV contact potential**
- **Quick disconnect screw terminal connections**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A.

CONNECTOR TYPE: Quick disconnect block for each channel. Screw terminals accept #14–#26 AWG wire.

RELAY DRIVE CURRENT: 80mA per relay typical.

MAXIMUM SIGNAL LEVEL: 250V DC or rms, 350V peak switched, 2A DC or rms, 60W DC or rms. 60W DC, 125VA AC (resistive load).

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CONTACT LIFE: $>10^8$ closures cold switching; $>10^5$ closures at maximum ratings.

CONTACT RESISTANCE: <0.1Ω initial, <2Ω rated life.

CONTACT POTENTIAL: <30µV per contact pair input to output with copper leads (<10µV typical).

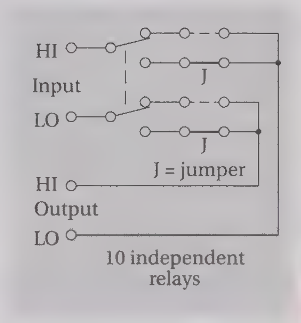
ACTUATION TIME: <10ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9\Omega$.

INPUT ISOLATION: $>10^9\Omega$.

COMMON MODE VOLTAGE: 350V peak.

OPERATING ENVIRONMENT: –25° to 65°C.



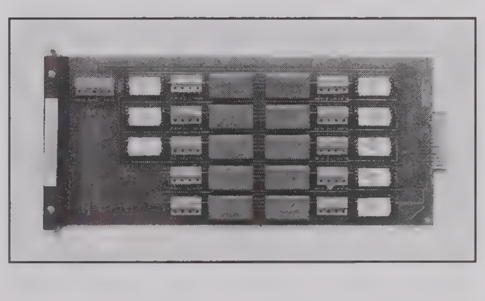
10 independent relays

4-Wire Scanner Card

7067

4-wire or Kelvin connections are generally made to minimize errors created by I-R drops in the cabling and interconnects of a test system. Each channel of the 7067 has two general purpose source contacts that switch currents up to 350mA, as well as two high quality contacts (<1µV contact potential) for dry switching of voltage to the sensing circuit.

The 7067 is well suited to precision resistance measurements as required in temperature coefficient testing. Other applications include remote sensing of voltage source outputs and bridge measurements.



- **4-wire, 10-channel scanner**
- **<1µV contact potential**
- **4-pole Form A relays**
- **Quick disconnect screw terminal connections**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 4-pole Form A, common shield connection.

CONNECTOR TYPE: Quick disconnect screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 40mA per channel typical.

SENSE LINES:
- **Maximum Signal Level:** 150V, 100mA, 2VA (resistive loads only).
- **Contact Resistance:** <0.5Ω initial, 2Ω to rated life.
- **Contact Potential:** <1µV per contact pair.

SOURCE LINES:
- **Maximum Signal Level:** 150V, 350mA, 10VA (resistive loads only).
- **Contact Resistance:** <0.2Ω initial, 2Ω to rated life.
- **Contact Potential:** <50µV per contact pair.

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

WARM-UP: 1 hour for thermal stability.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9\Omega$, <10pF.

INPUT ISOLATION, DIFFERENTIAL: $>10^9\Omega$, <50pF.

INPUT ISOLATION, COMMON MODE: $>10^9\Omega$, <100pF.

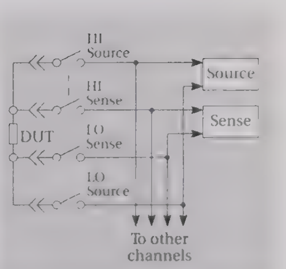
COMMON MODE VOLTAGE: <150V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25°C to 65°C.

APPLICATIONS: 4-wire resistance (resistors, relays, connectors, switches, RTDs). External sensing on voltage sources. DUT in/out switching (potentiometers, isolation amplifiers, strain gages).

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

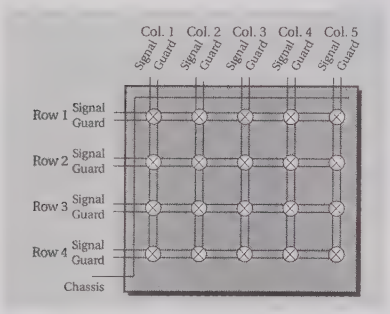


7152

4×5 Low Current Matrix Card

- **Sub-pA offset current**
- **Easy interconnect and expansion**
- **Maximum signal, 200V and 1A**
- **Standard mass terminated cable accessories**

The 7152 is an ideal solution for small to moderate-size matrix systems which require superior performance in DC isolation for measurements of semiconductor parameters and insulating properties of materials. Offset current is <1pA with path isolation $>10^{13}\Omega$. Each matrix crosspoint is a two-pole relay with the ability to switch both signal and guard or signal and sense circuits.



Interconnect, expansion of the matrix, and connection to instruments and devices are easily accomplished using two standard interconnect cable assemblies. The 7152-MTC cables are terminated at both ends with M-series connector blocks for quick expansion between cards and connection to 7152-MTR bulkhead receptacles. 7152-TRX cables are terminated at one end with M-series connectors and at the other end with 3-lug triaxial connector shells for direct connection to electrometers and SMUs.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

MATRIX CONFIGURATION: 4 rows by 5 columns.

CROSSPOINT CONFIGURATION: 2-pole Form A (Signal and Guard).

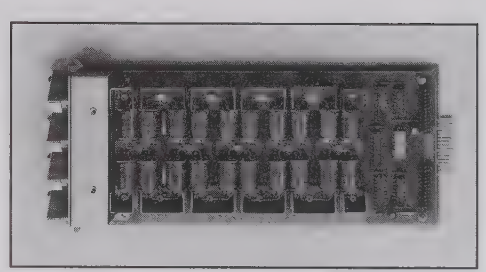
CONNECTOR TYPE: Subminiature coax, M-Series receptacle.

RELAY DRIVE CURRENT: 20mA (per crosspoint).

PEAK CONTACT RATING: 200V, 1A carry/0.5A switched. 10VA (resistive load).

PEAK VOLTAGE: Common Mode: 200V (signal or guard to chassis). **Path–Path:** 200V (Signal or Guard to Signal or Guard).

CONTACT LIFE: 10^8 closures (cold switching), 10^5 closures (at maximum signal level).



PATH RESISTANCE: <2Ω per contact to rated life.

ACTUATION TIME: <2ms exclusive of mainframe.

ISOLATION: Path: $>10^{13}\Omega$ and <1pF. **Differential:** $>10^{11}\Omega$ and <100pF. **Common Mode:** $>10^{9}\Omega$ and <300pF.

CROSSTALK: <–50dB at 1 MHz, 50Ω load.

INSERTION LOSS: 0.1dB typical (1MHz, 50Ω source, 50Ω load).

3dB BANDWIDTH: 60MHz typical (50Ω load).

OFFSET CURRENT: <1pA (10fA typical).

CONTACT POTENTIAL: 20μV per contact typical.

ENVIRONMENT: ISOLATION and OFFSET CURRENT Specifications: 23°C, <60% R.H. **Operating:** 0° to 50°C, up to 35°C at 70% RH. **Storage:** –25° to 65°C.

ACCESSORIES SUPPLIED: Connector caps.

ACCESSORIES AVAILABLE:

7074-CIT	Extraction Tool for 7152-KIT, 7152-MTR shield contacts
7074-HCT	Hand Crimp Tool for 7152-KIT, 7152-MTR shield contacts
7152-HCT	Hand Crimp Tool for 7152-KIT, 7152-MTR coaxial contacts
7152-MTC-2	Low Noise Matrix Expansion Cable, 0.6m (2 ft.)
7152-MTC-10	Low Noise Matrix Expansion Cable, 3m (10 ft.)
7152-TRX-10	Low Noise M-Series to Triax Cable, 3m (10 ft.)
7152-KIT	6-Position M-Series Plug with subminiature pins
7152-MTR	6-Position M-Series Receptacle, with subminiature sockets

7153

4×5 High Voltage Low Current Matrix Card

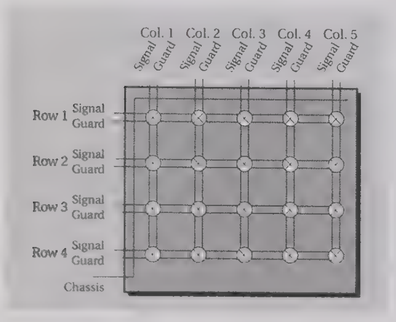
- **1300V switching**
- **Sub-pA offset current**
- **2-pole switching**
- **Mass termination connectors**

The 7153 is designed to switch low level, high voltage, and high impedance signals for applications such as parametric tests on semiconductor devices. The 7153 allows signal levels up to 1300V while maintaining offset current of <1pA (typically 10fA) and path isolation $>10^{13}\Omega$. Each crosspoint is a 2-pole relay to switch both signal and guard or signal and sense circuits.

Interconnect between the matrix and instruments such as the 237 SMU is done with the 7153-TRX. This cable is has an M-series connector for the matrix and five 3-slot male triax connectors at the opposite end. The cable will mate with the row or column connectors of the 7153.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**



MATRIX CONFIGURATION: 4 rows by 5 columns.

CROSSPOINT CONFIGURATION: 2-pole Form A (Signal and Guard).

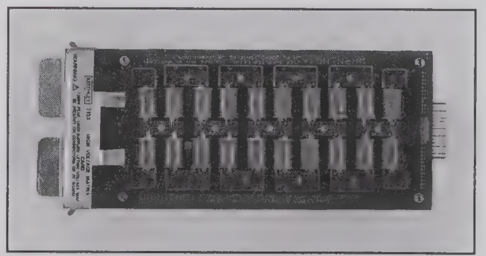
CONNECTOR TYPE: Miniature coax, M-series plug.

RELAY DRIVE CURRENT: 40 mA (per crosspoint).

MAXIMUM SIGNAL LEVEL: 1300V between any 2 signal pins or chassis; 200V between Signal and Guard. 1A carry/0.5A switched. 10VA peak (resistive load).

CONTACT LIFE: 10^8 closures (cold switching). 10^5 closures (at maximum signal level).

PATH RESISTANCE: <1Ω per contact to rated life.



ACTUATION TIME: <2ms exclusive of mainframe.

ISOLATION: Path: $>10^{13}\Omega$ and <1pF.
Differential: $>10^{11}\Omega$ and <100pF.
Common Mode: $>10^{9}\Omega$ and <300pF.

CROSSTALK: <–50dB at 1MHz, 50Ω load.

INSERTION LOSS: 0.1dB typical (1MHz, 50Ω source, 50Ω load).

3dB BANDWIDTH: 60MHz typical (50Ω load).

OFFSET CURRENT: <1pA (10fA typical).

CONTACT POTENTIAL: <50μV typical.

ENVIRONMENT:
ISOLATION and OFFSET CURRENT Specifications: 23°C, <60% R.H.
Operating: 0° to 50°C, up to 35°C at 70% R.H.
Storage: –25° to 65°C.

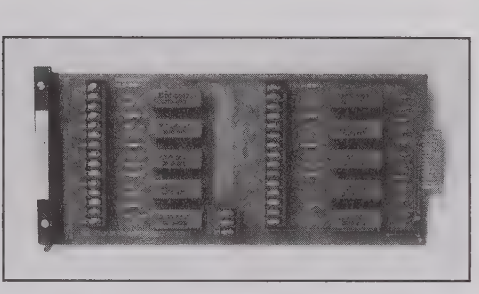
ACCESSORY AVAILABLE:

7153-TRX Low Noise M-Series to Triax Cable, 1.5m (5 ft.).

High Voltage Scanner Card

7154

The 7154 switches voltages to 1100V peak or currents to 0.5A. The current carry capacity of each relay contact is 1A. 2-pole relays switch both circuit High and Low for full floating measurements, and each input line is fuse protected against catastrophic failure. A Guard input common to all channels is provided for shielding or as a Guard driven from a single instrument. Guards may be isolated by removing jumpers installed at each input. Multiple switched guard circuits can be achieved by removing the jumper and connecting circuit Guard to the Low input terminal.



- 1100 volts peak
- 10 channels
- 2-pole switching
- High and low fused

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A with user-selectable shield or driven Guard. Each pole is fused using No. 38 AWG magnet wire.

CONNECTOR TYPE: Screw terminals, No. 16 AWG maximum wire size.

RELAY DRIVE CURRENT: 57mA per relay typical.

MAXIMUM SIGNAL LEVEL: 1100V peak, 0.5A DC or rms switched, 1A DC or rms carry, 10W.

CONTACT LIFE: >10^8 closures (cold switching); >5×10^6 closures (at maximum signal level).

CONTACT RESISTANCE: <200mΩ initial, 2Ω to rated life.

CONTACT POTENTIAL: <35μV per contact pair with copper leads.

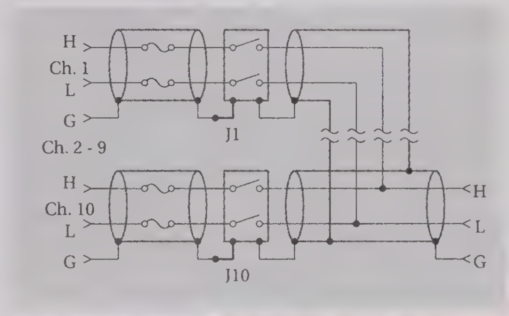
ACTUATION TIME: <2ms exclusive of mainframe.

CHANNEL ISOLATION: 10^{10}Ω, <10pF.

INPUT ISOLATION: Differential: >10^9Ω, <10pF. **Common Mode:** >10^9Ω, <150pF.

COMMON MODE VOLTAGE: 1100V peak.

ENVIRONMENT: Operating: 0° to 50° up to 35°C at 70% R.H. **Storage:** –5° to +65°C.



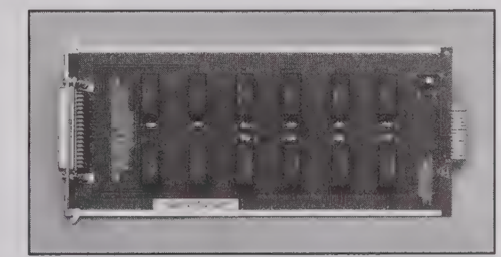
General Purpose Multiplex Cards

7156-D 7156-M

The 7156 consists of 10 channels of 2-pole multiplex switching when operated in 2-pole mode. A separate 1-pole output expands the card capacity to 20 channels of scanning when operating in the 1-pole mode. A removable jumper in the high lead of each channel allows individual channels to be configured as isolated, single pole, Form A relay contacts for actuator switch applications.

The dry reed version, 7156-D, provides excellent performance at an economical price. Or choose the 7156-M with mercury wetted relay contacts for improved reliability, higher current switching, and bounceless contact closure.

A 37-pin subminiature D-connector provides quick termination and disconnect when using the 7156-MTC Mass Terminated Cable Assembly. Mating connectors (7156-MTR) are available for bulkhead mount to test interface or breakout panels.



- 7156-D: Dry reed contacts for economy
- 7156-M: Mercury-wetted relays for bounceless contact closure
- Easy interconnect with 37-pin mass terminated subminiature D-connector
- Standard accessory cables

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CHANNELS PER CARD: 10 in 2-pole mode, 20 in 1-pole mode.

CONTACT CONFIGURATION: 2-pole Form A. HI or LO switched to a separate output for 1-pole mode. Removal of factory installed jumper creates a SPST isolated switch at each channel.

CONNECTOR TYPE: 37 pin D-sub.

RELAY DRIVE CURRENT:
- **7156-D:** 30mA per relay typical.
- **7156-M:** 50mA per relay typical.

MAXIMUM SIGNAL LEVEL:
- **7156-D:** 150V peak, 0.5A rms switched, 1A rms carry, 10VA (resistive load only).
- **7156-M:** 150V peak, 0.75A rms switched, 1A rms carry, 30VA.

CONTACT LIFE:
- **7156-D:** >10^8 closures cold switching; >10^7 closures at maximum signal levels
- **7156-M:** >10^9 closures cold switching; >10^8 closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL:
- **7156-D:** <100μV per contact pair, <50μV typical.
- **7156-M:** <100μV per contact pair, <75μV typical.

ACTUATION TIME:
- **7156-D:** <2ms, exclusive of mainframe.
- **7156-M:** <3ms, exclusive of mainframe.

CHANNEL ISOLATION: >10^9Ω, <150pF.

INPUT ISOLATION:
- **Differential Mode:** >10^9Ω, <50pF.
- **Common Mode:** >10^9Ω, <150pF.

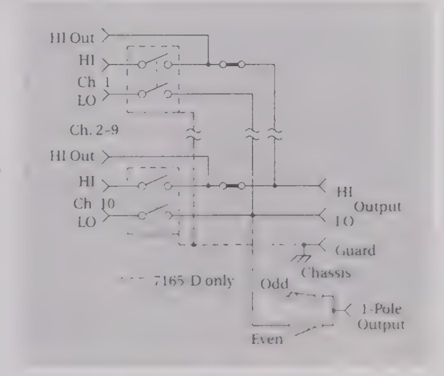
COMMON MODE VOLTAGE: 150V peak.

OPERATING ENVIRONMENT: 0° to 55°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25° to 65°C.

ACCESSORIES AVAILABLE:

7156-MTR	37-Pin Mass Terminated Bulkhead Mount Receptacle
7156-MTC	Mass Terminated Cable Assembly, 3m (10 ft.)



7158 Low Current Scanner Card

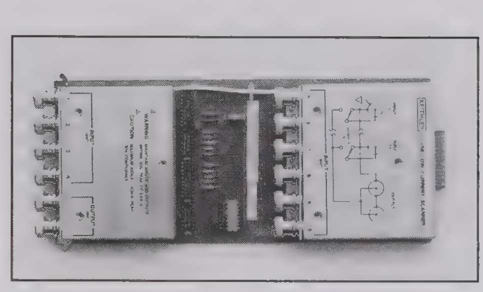
- **Sub-picoamp offset current**
- **10-channel scanner**
- **Maintains current path for unselected channel**
- **BNC connectors**

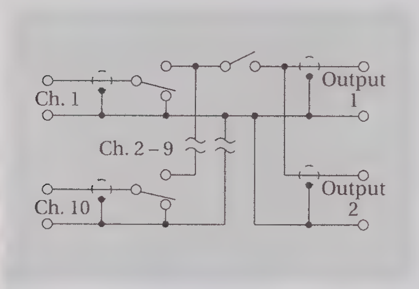
USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call:
1-800-552-1115 (U.S. only).

The 7158 provides quality low current switching at an affordable price. The offset current error generated is specified <1pA, with typical performance at <30fA.

When used with a voltage source and electrometer or picoammeter, this card can easily automate insulation resistance tests, reverse leakage tests on semiconductor junctions, or gate leakage tests on FETs.

The Model 7158 is designed to maintain the current path even when the channel is de-selected. Input connectors are BNC for shielding of the sensitive measurements and for compatibility with low noise coaxial cables such as Keithley accessory cable Models 4801 and 4803. Two outputs are provided to allow for chaining of several scanner cards to one measurement instrument, and an isolation relay in the output HI minimizes interaction between cards.





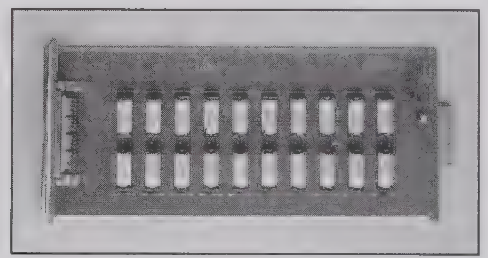
CHANNELS PER CARD: 10.
CONTACT CONFIGURATION: Single pole, simultaneous break and make for signal HI input. Signal LO is common for all 10 channels and output. When a channel is off, signal HI is connected to signal LO.
CONNECTOR TYPE: BNC.
RELAY DRIVE CURRENT: 10mA per relay typical.
SIGNAL LEVEL: 35mA maximum, 30V compliance maximum (non-inductive load only).
CONTACT LIFE: >10^6 closures at maximum signal levels; >10^7 closures at low signal levels.
CONTACT RESISTANCE: <1Ω.
CONTACT POTENTIAL: <200μV.
OFFSET CURRENT: <1pA (<30fA typical).
3dB BANDWIDTH: 1MHz typical.
ACTUATION TIME: <1ms, exclusive of mainframe.
COMMON MODE VOLTAGE: <30V maximum.
OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.
STORAGE ENVIRONMENT: –25°C to 65°C.
ACCESSORY SUPPLIED: Model 4801 Low Noise Cable.
ACCESSORIES AVAILABLE:
4803: Low Noise Cable Kit (with male and female BNCs)
4804: Female Triaxial to Male BNC Adapter.

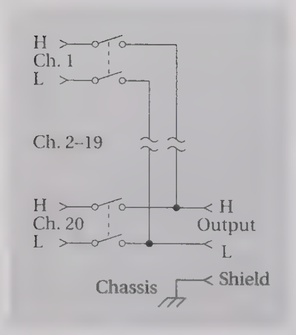
7164-D 7164-M 20-Channel Scanner Cards

- **High density, low cost scanning for 705 and 706**
- **Easier interconnect and cabling**
- **7164-M: High reliability and bounceless contact closure**
- **7164-D: Economy with full specifications**

The 7164-D and 7164-M are 20-channel, 2-pole scanner cards (sequential switching) for use in high density switching systems: up to 1000 points with the 706 mainframe or 200 points with the 705. The cards reduce system integration and maintenance costs by using standard 50-pin D-connectors and terminations to twisted pair ribbon cable for ease of assembly and interconnect.

The 7164-D uses dry reed relays for economy with fully specified performance; the 7164-M uses mercury-wetted relays for higher reliability and current switching capacity. Mercury-wetted relays also ensure bounceless contact closure and consistent contact resistance over rated life.





	7164-D	7164-M
CONTACT TYPE	Dry reed	Mercury wetted
RELAY DRIVE CURRENT (typical)	30 mA	50 mA
MAXIMUM SIGNAL:		
Voltage	100V peak	100 V peak
Current (switched)	0.5 A rms	0.75 A rms
Current (carry)	1.0 A rms	1.0 A rms
V•A (resistive load)	10 VA	30 VA
CONTACT RESISTANCE		
Initial	<400 mΩ	<400 mΩ
At rated life	<2 Ω	<400 mΩ
CONTACT LIFE		
Cold Switching	>10^8	>10^9
Max. Signal	>10^7	>10^8
CONTACT POTENTIAL		
Per Contact Pair	<50 μV	<75 μV

CHANNELS PER CARD: 20.
CONTACT CONFIGURATION: 2-pole Form A, common guard/shield connection.
CONNECTOR TYPE: 50-pin D connector.
ACTUATION TIME: <2ms, exclusive of mainframe.
CHANNEL ISOLATION: >10^9Ω, <20pF.
INPUT ISOLATION: Differential: >10^9Ω, <50pF. **Common Mode:** >10^9Ω, <150pF.
CHANNEL TO CHANNEL VOLTAGE: 100V peak.
COMMON MODE VOLTAGE: 200V peak.
ENVIRONMENT: Operating: 0° to 50°C, up to 35°C at 70% R.H. **Storage:** –25° to 65°C.
ACCESSORY SUPPLIED: Mating connector, solder cup.
ACCESSORIES AVAILABLE:
7164-MTC-10: Cable Accessory, 10 ft. twisted pair
7164-KIT: 7064 Mating Connector

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call:
1-800-552-1115 (U.S. only).

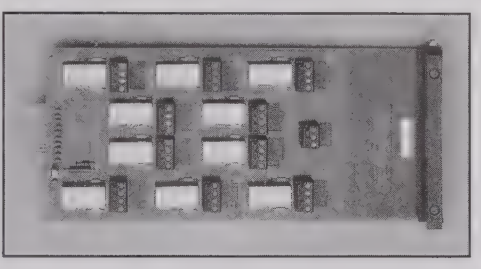
Mercury Wetted Relay Card

7166

The 7166 consists of 10 two-pole, mercury wetted, reed relays and comes configured as a 1×10 multiplex scanner. That is any or all of the 10 (2-pole) input channels can be routed to the output.

The relay card can be configured for use as a 10 channel switching card by removing jumpers installed on the card. In this configuration, up to 10 independent inputs can be individually controlled and switched to a corresponding isolated output.

The use of mercury wetted relays provides for reliable switch contacts under a wider variety of operating conditions. Mercury wetted relays also help assure bounce-free actuation and more consistent contact resistance over the life of the relay.



Applications for the Model 7166 include actuation and control of external relays and circuits, general purpose signal switching (above 100μV), board and component level tests.

- **Mercury wetted relays**
- **10-channel scanner**
- **2-pole Form A**
- **Quick disconnect screw terminal connections**

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole, Form A; 1 of 10 selectable or 10 isolated channels.

CONNECTOR TYPE: Quick disconnect screw terminals, No. 14 AWG maximum wire size.

RELAY DRIVE CURRENT: 75mA per relay typical.

MAXIMUM SIGNAL LEVEL: 300V peak. 0.75A DC or rms switched. 2A DC or RMS carry. 30VA.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CONTACT LIFE: $>4 \times 10^8$ closure (cold switching); $>5 \times 10^7$ closures (at maximum signal levels).

CONTACT RESISTANCE: <150mΩ to rated life.

CONTACT POTENTIAL: <75μV per contact pair with copper leads typical.

ACTUATION TIME: <3ms, exclusive of mainframe.

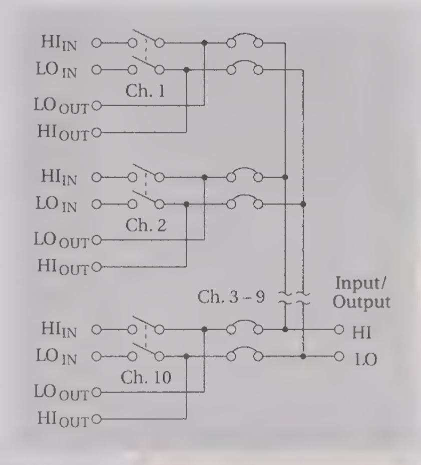
CHANNEL ISOLATION: $10^{10}\Omega$, <10pF.

INPUT ISOLATION: Differential: $>10^9\Omega$, <50pF. **Common Mode:** $>10^9\Omega$, <150pF.

COMMON MODE VOLTAGE: 300V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% R.H.

STORAGE ENVIRONMENT: –25° to 65°C.

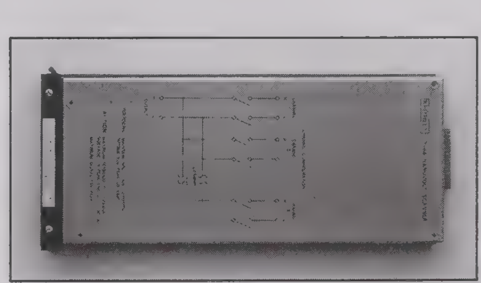


Nanovolt Scanner Card

7168

The 7168 is an eight-channel, two-pole card with <20nV of thermal offset. It will switch any one of eight signals to one output in less than 3ms. Channel offset leakage current is <50pA at 23°C.

Keithley also offers the Model 78, which includes the 7168 Nanovolt Scanner Card, Model 705 20-Channel Scanner mainframe, and Model 182 Sensitive Digital Voltmeter. When the 7168 is used with the Model 182, the noise and drift performance of the 182 is not degraded.



- **<30nV contact potential**
- **8-channel scanner**
- **2-pole Form A**
- **Bare copper terminal connections**

CHANNELS PER CARD: 8.

CONFIGURATION: Two poles per channel, input HI and LO.

CONNECTOR TYPE: Screw terminal to bare copper printed circuit pad.

MAX. SIGNAL LEVEL: 10V, 50mA peak (resistive load only).

CONTACT RESISTANCE: <12Ω.

CONTACT POTENTIAL (HI to LO) BETWEEN CHANNELS: <30nV when properly zeroed with supplied leads (see manual for recommended procedure). Typically <60nV without zeroing.

USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CONTACT TYPE: Solid state JFET switch.

ACTUATION TIME: <3ms, exclusive of mainframe.

INPUT LEAKAGE: <50pA per channel at 23°C.

INPUT ISOLATION: $>10^9\Omega$, <40pF between any input terminals or between any input terminal and earth.

COMMON MODE VOLTAGE: 30V peak.

MAXIMUM VOLTAGE BETWEEN ANY TWO TERMINALS: 10V.

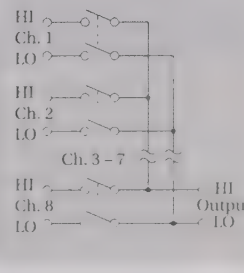
WARM-UP: 2 hours in mainframe for thermal stability.

OPERATING ENVIRONMENT: 0°–40°C; up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25° to 60°C.

ACCESSORIES SUPPLIED: Model 7168-316 Input Cable (8 supplied); Model 1507 Low Thermal Input Cable.

ACCESSORIES AVAILABLE: Model 1483 Low Thermal Connection Kit.

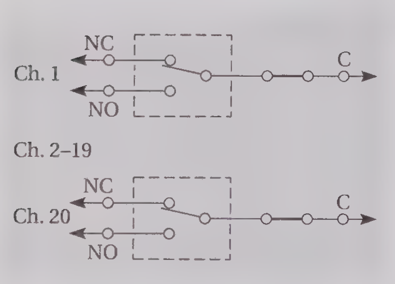


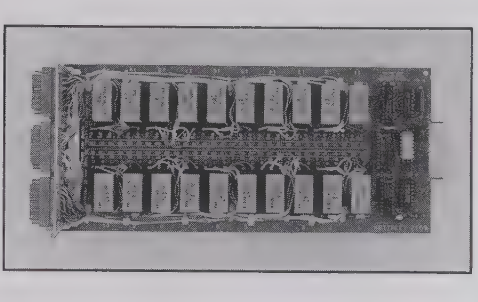
20-Channel Form C Switch Card

- **20 independent Form C relays**
- **500V peak**
- **Mass termination connectors**

Each channel of the 7169 is a single-pole, double-throw isolated switch. There are two undedicated buses on the card that can be jumpered to interconnect channels or change the card configuration from switch to multiplex. Factory installed jumpers in series with the COMMON terminal can be removed if a limiting resistor is required.

All poles are available at the three 20-pin mass terminators, which provide quick termination and disconnect when using Model 7169-MTC-3 Mass Terminated Cables or Model 7169-KIT connectors.





USE WITH MODELS 705 AND 706 SCANNER MAINFRAMES
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

CHANNELS PER CARD: 20 independent Form C. All poles available at connectors. Replacement of factory installed jumper allows current limit resistor in series with common of each channel. On-card bus allows for addition of jumper to change configuration from switch to multiplex. Bus also allows channel interconnection.

CONNECTOR TYPE: 3 × 20 pin mass termination.

RELAY DRIVE CURRENT: 30mA per relay typical.

MAXIMUM SIGNAL LEVEL: 500V peak, 0.5A rms switched, 1A rms carry, 10W (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^7$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <30μV, C to NO or NC.

ACTUATION TIME: <1ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9\Omega$, <150pF.

INPUT ISOLATION: $>10^9\Omega$, <150pF.

COMMON MODE VOLTAGE: 500V peak.

OPERATING ENVIRONMENT: 0° to 55°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25°C to 65°C.

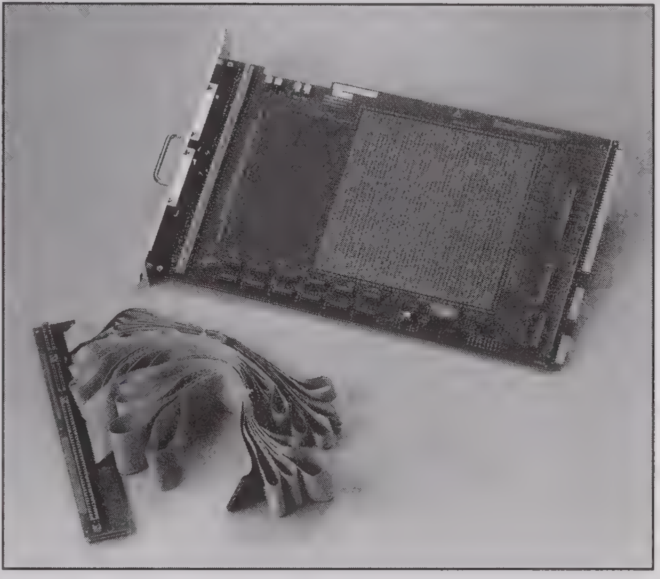
ACCESSORIES AVAILABLE:

7169-KIT	20-Pin Mass Terminated Connector
7169-MTC-3	Mass Terminated Cable Assembly, 3m (10 ft.)
7169-MTR	Mass Terminated Bulkhead Mount Receptacle

Universal Adapter Card, Prototype Circuit Assembly

7070,7070-PCA

The **Model 7070 Universal Adapter Card** extends relay control and analog backplane signals through a supplied ribbon cable and connector assembly for the purpose of test and fault isolation on 707 switching cards. This adapter facilitates system maintenance by allowing for easy access to all electrical circuits on a switching card while running the relay test software provided with each 707 mainframe.



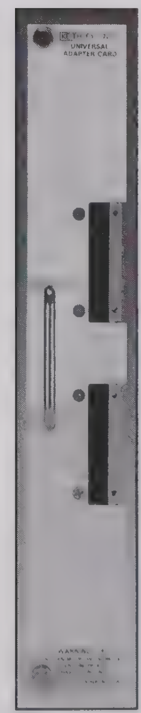
Approximately 117 square inches of breadboard area, with mounting holes spaced on 0.1 inch centers, is available for development of unique circuits and switching topologies. 96 open collector drivers can be used to control special circuits such as microwave or high power relays. User defined circuits and components can be mounted on this assembly and used for system verification and calibration.

The **Model 7070-PCA Prototype Circuit Assembly** is available without the extender ribbon cable and connector assembly used for maintenance and troubleshooting of other relay cards. This model is for breadboard and circuit prototype applications only.

- **7070: Circuit prototype and breadboard with extender cable**
- **7070-PCA: Breadboard without extender cable**

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**



DESCRIPTION: Backplane extender card for 707 matrix cards or breadboard card, jumper selectable. Access to analog and digital backplanes, relay drivers, and power supplies.

MAXIMUM SIGNAL LEVEL (BACKPLANE): 200V, 1A.

COMMON MODE VOLTAGE (BACKPLANE): 200V maximum between any two pins or chassis.

SUPPLY SPECIFICATIONS: 6V, 2.9A* maximum; 5V, 500mA maximum, digital supply.

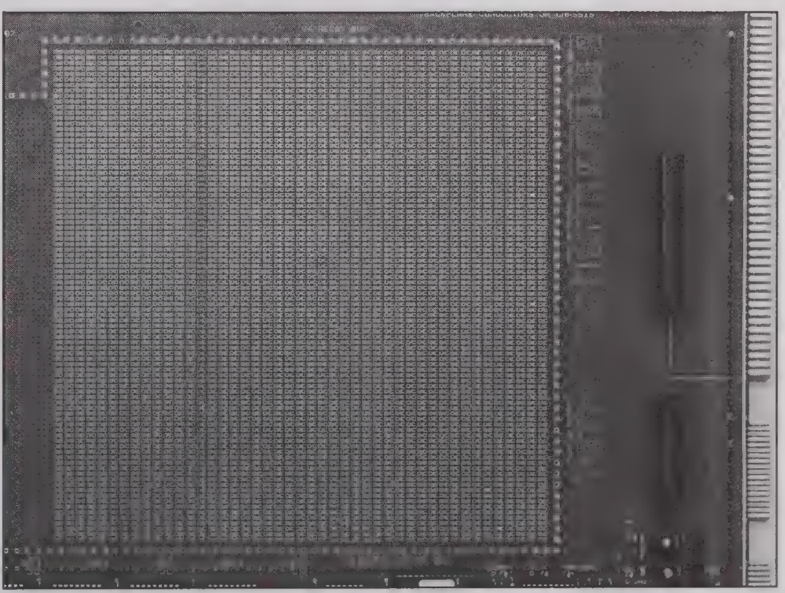
*Assuming no other cards are installed. See individual card specifications for their relay drive requirements.

RELAY DRIVE LINES: 96 open collector sink drivers, 140mA each. Coded in 8 row × 12 column format for front panel display. User may provide external coil voltage supply up to 35V or use mainframe 6V supply.

BREADBOARD SPACE: Approximately 330mm × 228mm (13 in. × 9 in.).

RIBBON CABLE: Extends analog and digital backplanes 10 feet for benchtop servicing of cards.

CONNECTOR TYPE: 20 quick disconnect with 3 screw terminals. 2 strain relief clamps.



Breadboard area of Model 7070 and 7070-PCA provides approximately 117 square inches for custom circuit development or mounting special components.

7071

8×12 General Purpose Matrix Card

- 96 3-pole, Form A relay crosspoints
- High, Low, and Guard switched
- <5µV contact potential per crosspoint
- Signals to 200V and 1A

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

The Model 7071 General Purpose Matrix Card is an 8x12 configuration which switches High, Low, and Guard at each of the 96 relay crosspoints. The 8 rows are connected automatically to the general purpose analog backplane when the matrix card is installed into the 707 mainframe. This allows for easy expansion in 12 column increments, and eliminates the requirement for wiring between cards.

The matrix card will handle voltages up to 200V and currents up to 0.5A switched, or 1A unswitched. A 5µV contact potential assures that the switch does not adversely affect low voltage sensitivity. The 3dB signal bandwidth is 5MHz. Guard inputs improve isolation between signals and assure <100pA offset currents into any electrical path.

Connection to the Model 7071 is made to either the matrix columns or the matrix rows through one of two convenient 38-pin connectors. A 20 ft. pre-assembled cable accessory is available, Model 7078-MTC Mass Terminated Cable Assembly. This cable may be used as is with mating connector, or cut to length and routed to various termination points within the system. Or, mating cables may be assembled using the Model 7078-KIT Connector Kit, 7078-CIT Contact Insertion and Extraction Tool, and 7078-HCT Hand Crimp Tool.

MATRIX CONFIGURATION: 8 rows by 12 columns.

CROSSPOINT CONFIGURATION: 3-pole Form A (HI, LO, GUARD).

CONNECTOR TYPE: Quick disconnect using 38-pin connectors or screw terminals.

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

CONTACT LIFE: Cold Switching: 10^8 closures. **At Maximum Signal Level:** 10^5 closures.

PATH RESISTANCE (per conductor): <0.6Ω initial, <1.5Ω at end of contact life.

CONTACT POTENTIAL: <5µV per crosspoint (HI to LO <1 minute after actuation).

OFFSET CURRENT: <100pA.

ISOLATION: Path: $>10^{10}\Omega$, <10pF. **Differential:** $10^9\Omega$, 45pF nominal. **Common Mode:** $10^9\Omega$, 165pF nominal.

CROSSTALK: <–50dB at 1MHz, 50Ω load.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.1dB typical.

3dB BANDWIDTH (50Ω load): 5MHz typical.

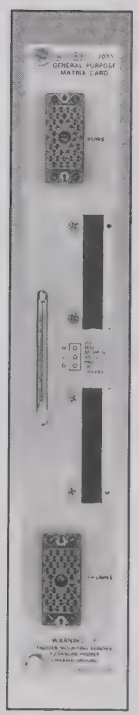
RELAY DRIVE CURRENT (per crosspoint): 15mA.

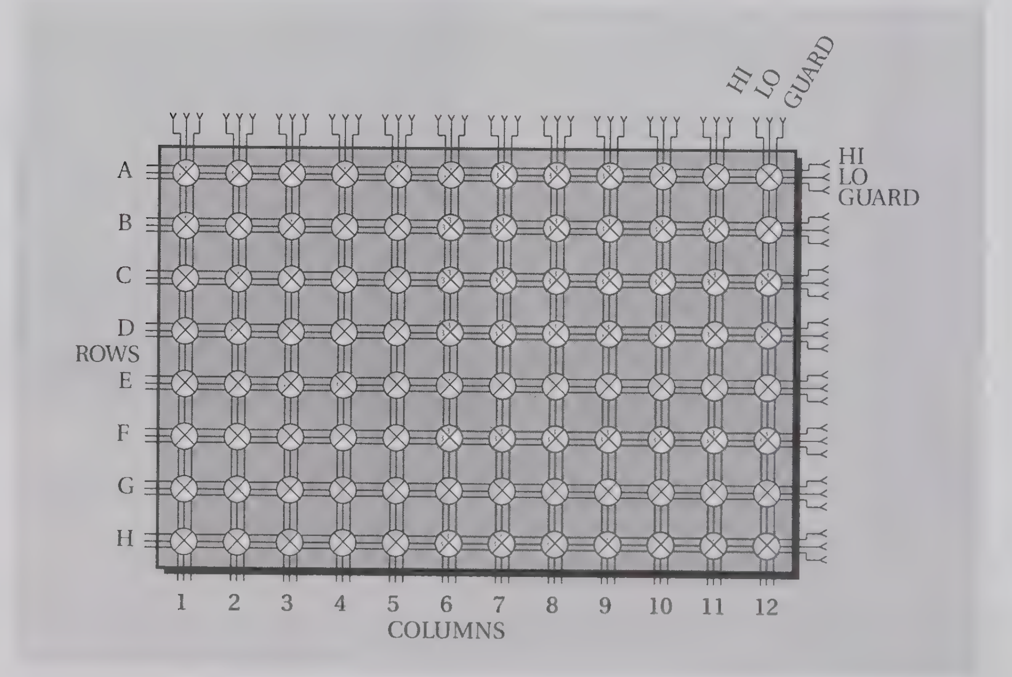
RELAY SETTLING TIME: <3msec..

ENVIRONMENT: Operating: 0° to 50°C, up to 35°C at 70% R.H. **Storage:** –25 to +65°C.

ACCESSORIES AVAILABLE:

7078-CIT:	Contact Insertion and Extraction Tools
7078-HCT:	Hand Crimping Tool
7078-KIT:	Connector Kit
7078-MTC:	Mass Terminated Cable Assembly, 6m (20 ft.)

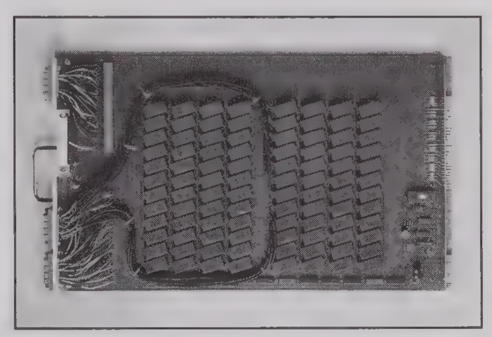




Dual 4×12 General Purpose Matrix Card

7071-4

The Model 7071-4 Dual 4×12 General Purpose Matrix Card provides the capability to expand the number of columns which the Model 707 Switching Matrix will support to a maximum of 720 in five mainframes. This matrix card has two banks of four signal paths which connect through jumpers to the General Purpose Analog Backplane in the 707 mainframe for automatic interconnect between cards. Jumpers may be removed to isolate any 4×12 matrix segment, or repositioned to cascade segments into a 4×24 configuration.



Column connections to the matrix are through two 38-pin mass terminated connectors. The corresponding cable accessory, Model 7078-MTC, is constructed with 12 sets of shielded twisted pair circuits for excellent noise immunity and electrical separation. Custom cables and harnesses can be assembled using the Model 7078-KIT Connector Kit. The mating bulkhead connector, Model 7078-MTR, is also available.

- **Two independent 4×12 matrix switches**
- **3-pole switching (HI, LO, GUARD)**
- **Connect to General Purpose Analog Backplane**
- **Configuration easily adapted with jumpers**
- **4×24 or dual 4×12 configuration**

MATRIX CONFIGURATION: Dual 4 rows by 12 columns. Also configurable as 8 rows by 12 columns or 4 rows by 24 columns.

CROSSPOINT CONFIGURATION: 3 pole Form A (HI, LO, GUARD).

CONNECTOR TYPE: Quick disconnect using 38 pin connectors. In addition, screw terminals are available on rows.

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

CONTACT LIFE:
Cold Switching: 10^8 closures.
At Maximum Signal Level: 10^5 closures.

PATH RESISTANCE (per conductor): <0.6Ω initial, <1.5Ω at end of contact life.

CONTACT POTENTIAL: <5µV per crosspoint (HI to LO, <1 minute after actuation).

OFFSET CURRENT: <100pA (HI to LO).

ISOLATION:
Path: > $10^{10}\Omega$, <10pF.
Differential: $10^9\Omega$, 45pF nominal.
Common Mode: $10^9\Omega$, 300pF nominal.

CROSSTALK: <–45dB at 1MHz, 50Ω load.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.1dB typical.

3dB BANDWIDTH (50Ω load): 5MHz typical.

RELAY DRIVE CURRENT (per crosspoint): 15mA.

RELAY SETTLING TIME: <3msec.

ENVIRONMENT:
Operating: 0° to 50°C, up to 35°C at 70% R.H.
Storage: –25° to 65°C.

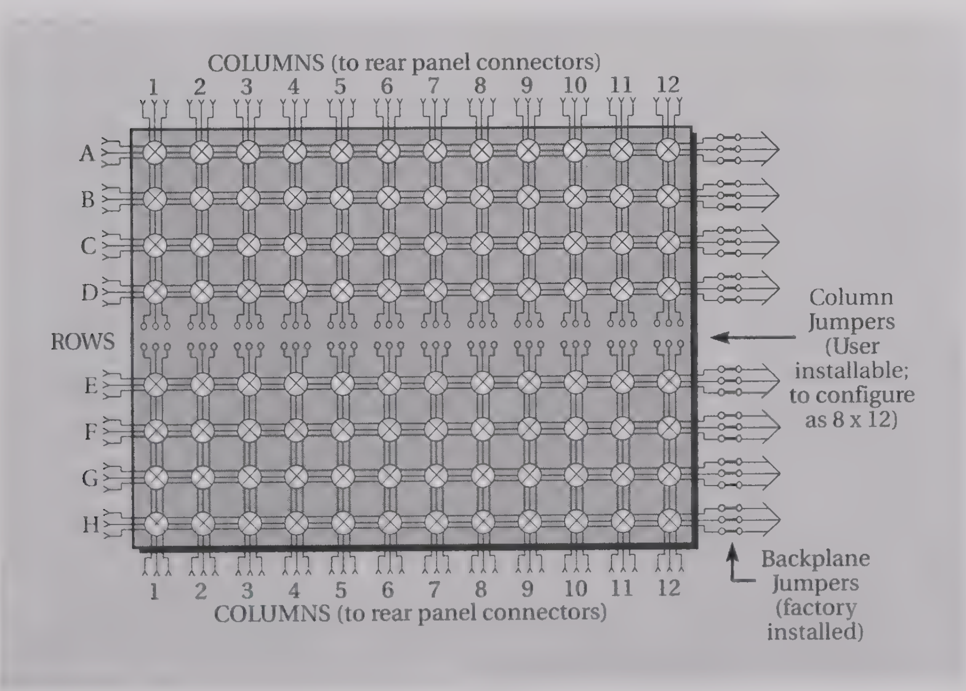
ACCESSORIES SUPPLIED: Screw terminal adapter for 4×24 configuration.

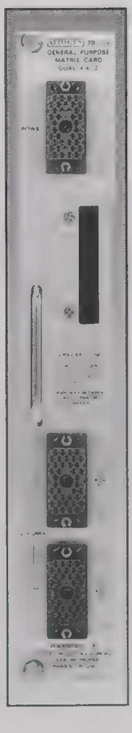
ACCESSORIES AVAILABLE:

7078-CIT:	Contact Insertion and Extraction Tools
7078-HCT:	Hand Crimping Tool
7078-KIT:	Mass Terminated Plug with Contacts
7078-MTC-5:	Mass Terminated Cable Assembly, 1.5m (5 ft.)
7078-MTC-20:	Mass Terminated Cable Assembly, 6m (20 ft.)
7078-MTR:	Mass Terminated Receptacle with Contacts

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**


COLUMNS (to rear panel connectors)
1 2 3 4 5 6 7 8 9 10 11 12
A
B
C
D
ROWS
E
F
G
H
Column Jumpers (User installable; to configure as 8 x 12)
Backplane Jumpers (factory installed)
1 2 3 4 5 6 7 8 9 10 11 12
COLUMNS (to rear panel connectors)



7072

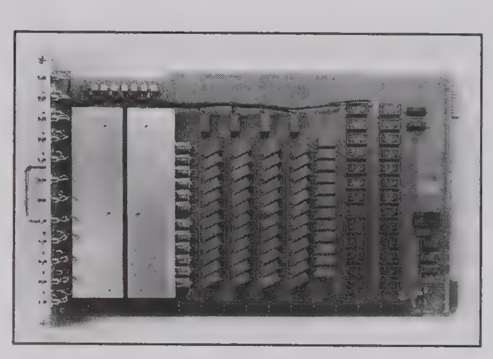
8×12 Semiconductor Matrix Card

- **Two sub-picoamp current paths**
- **Two DC to 1MHz C-V paths**
- **Four high isolation signal paths**
- **3-lug triaxial connection**

KEITHLEY 7072
SEMICONDUCTOR
MATRIX CARD
TRIAX
COLUMN
ROW
CAUTION
WARNING:
TIGHTEN MOUNTING SCREWS TO ENSURE PROPER CHASSIS GROUND
MADE IN U.S.A.

The Model 7072 Semiconductor Matrix Card is designed specifically to handle low level and high impedance measurements encountered in semiconductor parametric tests on wafers and devices. This unique design provides two low current circuits with specified 1pA maximum offset current for sensitive sub-picoamp measurement resolution, and two C-V paths for measurement of Capacitance Voltage characteristics from DC to 1MHz. Four additional high quality signal paths with <20pA offset current provide for general purpose signal switching up to 100nA or 200V.

Connections are 3-lug triax with the outer shell connected to chassis for safety and noise shielding. The center conductor is fully surrounded by the inner conducting shield, so that fully guarded measurements can be made to achieve higher isolation and to improve measurement speed and accuracy. These conductors can also be configured to switch both circuit high and low.



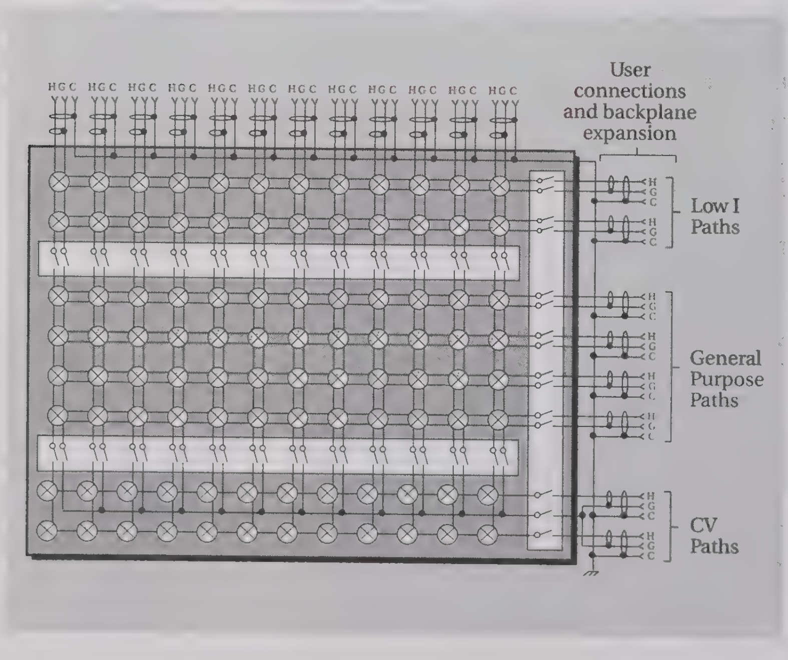
Isolation relays on the low current and C-V paths automatically disconnect unused circuits to achieve minimum interference and peak performance. The 707 mainframe will allow each row (signal path) to be programmed for Break Before Make or Make Before Break operation.

For applications requiring connections to a large number of devices or test points, the 7072 matrix can be expanded with additional cards. The low current and C-V rows can be extended to other cards with coaxial jumpers. The other four high-quality signal paths connect directly to the 707 backplane for expansion.

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

	LOW CURRENT (ROWS A–B)	GENERAL PURPOSE (ROWS C–F)	C-V (ROWS G–H)
CROSSPOINT CONFIGURATION:	2-pole Form A	2-pole Form A	1-pole Form A, Common Guard
OFFSET CURRENT:	<1 pA	<20 pA	<20 pA
PATH ISOLATION:			
Resistance:	$>10^{13}\,\Omega$	$>10^{12}\,\Omega$	$>10^{12}\,\Omega$
Capacitance (nominal):	0.4 pF	1 pF	0.6 pF
CROSSTALK			
1 MHz, 50Ω load (typical):	<–50 dB	<–40 dB	<–50 dB
3dB BANDWIDTH (typical), 50Ω Load:	15 MHz	8 MHz	5 MHz
RELAY DRIVE CURRENT (per crosspoint):	40 mA	60 mA	80 mA


HGC HGC HGC HGC HGC HGC HGC HGC HGC HGC HGC HGC
User connections and backplane expansion
H
G
C
Low I Paths
General Purpose Paths
CV Paths

MATRIX CONFIGURATION: 8 rows by 12 columns.

CONNECTOR TYPE: 3-lug triaxial (Signal, Guard, Chassis).

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

CONTACT LIFE: Cold Switching: 10^7 closures. **At Maximum Signal Level:** 10^5 closures.

PATH RESISTANCE (per conductor): <1Ω initial, <3.5Ω at end of contact life.

CONTACT POTENTIAL: <20μV per crosspoint (Signal to Guard).

RELAY SETTLING TIME: <15ms.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.1dB typical.

ENVIRONMENT:

OFFSET CURRENT and PATH ISOLATION Specifications: 23°C, <60% R.H.

Operating: 0° to 50°C, up to 35°C at 70% R.H.

Storage: –25° to +65°C.

ACCESSORIES AVAILABLE:

7078-TRX-BNC:	3-Lug Triax to BNC Adapter
7078-TRX-T:	3-Lug Triax Tee Adapter
7078-TRX-3:	3-Lug Triax Cable, 0.9m (3 ft.)
7078-TRX-10:	3-Lug Triax Cable, 3m (10 ft.)
7078-TBC:	3-Lug Female Triax Bulk- head Connector with Cap
7078-CSHP:	Cable Set to connect 7072 to HP 4145

High Voltage Semiconductor Matrix Card 7072-HV

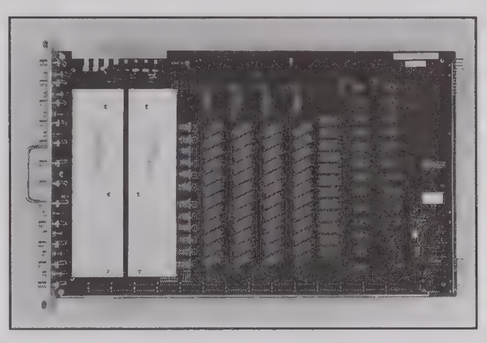
The Model 7072-HV is designed to switch low level, high voltage, and high impedance signals for semiconductor parametric tests on wafers and devices. This unique design provides two signal paths capable of switching 1300V with less than 1pA of offset current. The two C-V paths may be used for measurement of capacitance voltage characteristics from DC to 1MHz, or for switching low currents with a common ground. Four additional high quality signal paths with less than 20pA offset current provide for signal switching to 200V.

Connections are 3-lug triax with the outer shell connected to chassis for safety and noise shielding. The center conductor is fully surrounded by the inner conducting shield to provide fully guarded measurements with higher isolation and improved measurement speed and accuracy.

7072-HV Applications

The Model 7072-HV in conjunction with the Model 237 SMU or Model 487 Picoammeter/Voltage Source can address a wide variety of semiconductor device and material characterization needs.

The high voltage signals encountered in breakdown measurements or oxide integrity testing can be easily switched with this matrix card. Signals connected to the High V, Low I paths are automatically isolated from the rest of the card.



For applications requiring connections to a large number of devices or test points, the 7072-HV matrix can be expanded with additional cards. The high voltage and C-V rows can be extended to other cards with coaxial jumpers. The other four high-quality signal paths connect directly to the 707 backplane for expansion.

- **Two 1300V, sub-picoamp current paths**
- **Six 200V, 20pA paths**
- **For use with 237 SMU**
- **3-lug triaxial connections**

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

	LOW CURRENT (ROWS A - B)	GENERAL PURPOSE (ROWS C - F)	C-V (ROWS G - H)
CROSSPOINT CONFIGURATION	2-pole Form A	2-pole Form A	1-pole Form A, Common Guard
OFFSET CURRENT	<1 pA	<20 pA	<20 pA
PATH ISOLATION			
Resistance	$>10^{13}\,\Omega$	$>10^{12}\,\Omega$	$>10^{12}\,\Omega$
Capacitance (nominal)	0.4 pF	1 pF	0.6 pF
CROSSTALK			
1 MHz, 50Ω load (typical)	<–60 dB	<–40 dB	<–50 dB
3dB BANDWIDTH (typical), 50Ω Load	4 MHz	8 MHz	5 MHz
RELAY DRIVE CURRENT (per crosspoint):	40 mA	60 mA	80 mA
MAXIMUM SIGNAL LEVEL			
Maximum between any 2 pins or chassis:	1300V	200V	200V
Maximum between signal and guard:	200V	200V	200V
1A carry/0.5A switched, 10VA peak (resistive load)			
CONTACT POTENTIAL (Signal to Guard):	<50 µV	<20 µV	<20 µV

MATRIX CONFIGURATION: 8 rows by 12 columns.

CONNECTOR TYPE: Three-lug triaxial (Signal, Guard, Chassis).

CONTACT LIFE: Cold Switching: 10^7 closures. **At Maximum Signal Level:** 10^5 closures.

PATH RESISTANCE (per conductor): <1Ω initial, <3.5Ω at end of contact life.

RELAY SETTLING TIME: <15ms.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.1dB typical.

ENVIRONMENT:

OFFSET CURRENT and PATH ISOLATION Specifications: 23°C, <60% R.H.

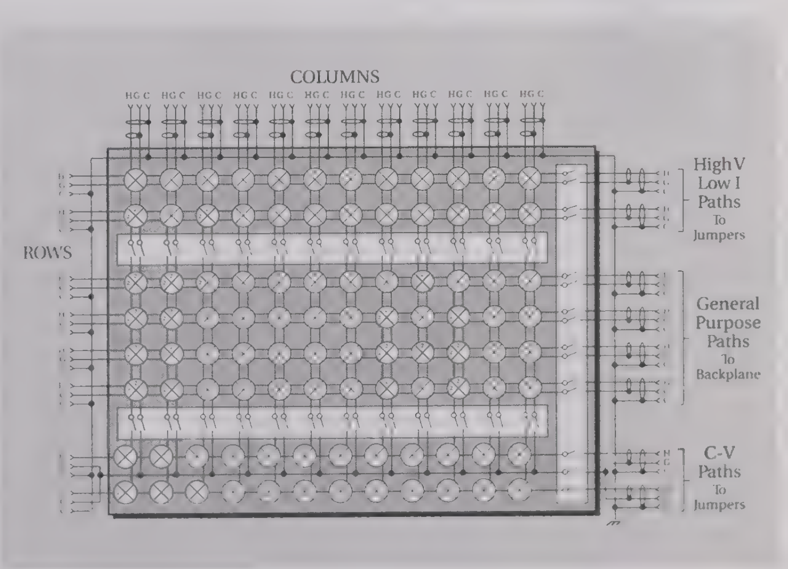
Operating: 0° to 50°C, up to 35°C at 70% R.H. **Storage:** –25° to +65°C.

ACCESSORIES AVAILABLE:

237-TRX-TBC: 3-Lug High Voltage Female Triax Bulkhead Connector
7078-TRX-3: 3-Lug Triax Cable, 0.9m (3 ft.)
7078-TRX-10: 3-Lug Triax Cable, 3m (10 ft.)
7078-TRX-BNC: 3-Lug Triax to BNC Adapter
7078-TRX-T: 3-Lug Triax Tee Adapter

For use at 200V or less:

7078-CSH: Cable Set to connect 7072-HV to HP4145
7078-TBC: 3-Lug Female Triax Bulkhead Connector with Cap


COLUMNS
HGC
ROWS
High V Low I Paths To Jumpers
General Purpose Paths To Backplane
C-V Paths To Jumpers

7073 8×12 Coaxial Matrix Card

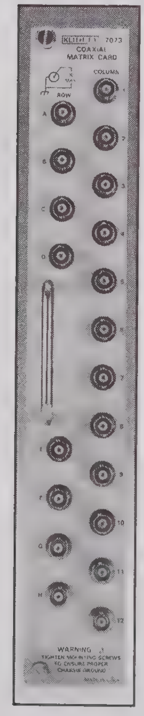
- 30MHz bandwidth
- Signals 2µV to 200V
- >80dB path isolation

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

The Model 7073 Coaxial Matrix Card provides fully shielded signal lines for excellent noise rejection in test systems. Isolation jumpers on the card can be removed to disconnect the card signal paths from the coaxial analog backplane, and the shield provides >80dB isolation at 1MHz between signal paths to minimize crosstalk and coupling of adjacent signals. The 30MHz bandwidth and the 50 ohm characteristic impedance minimize distortion and overshoot in high frequency and digital signals.

Contact potential for the Model 7073 is specified at <2µV which is useful when measuring sensitive voltage signals. The card can also switch voltages up to 200V. Current capacity of the matrix card is 1A for switching moderate power to test devices and circuits.



MATRIX CONFIGURATION: 8 rows by 12 columns.

CROSSPOINT CONFIGURATION: 1-pole Form A.

CONNECTOR TYPE: BNC (HI, Chassis).

MAXIMUM SIGNAL LEVEL: 200V, 1A, 30VA peak (resistive load). 200V maximum between any 2 pins or chassis.

CONTACT LIFE: Cold Switching: 10^7 closures. **At Maximum Signal Level:** 10^5 closures.

PATH RESISTANCE (per conductor): <0.5Ω initial, <1Ω at end of contact life.

CONTACT POTENTIAL: <2µV per contact.

OFFSET CURRENT: <200pA, 10pA typical.

PATH ISOLATION*: >$10^{10}\Omega$, <0.3pF.

CROSSTALK*:
- **1MHz, 50Ω load:** <–80dB.
- **10MHz, 50Ω load:** <–65dB.
- **1MHz, 1MΩ load:** <–55dB.

*Path isolation and crosstalk specified with backplane disconnect jumpers removed.

INPUT ISOLATION: $10^9\Omega$, 220pF nominal.

INSERTION LOSS (50Ω source):
- **50Ω load, 10MHz:** <0.5dB.
- **1MΩ load, 1MHz:** <0.2dB.

3dB BANDWIDTH (50Ω load): 30MHz typical.

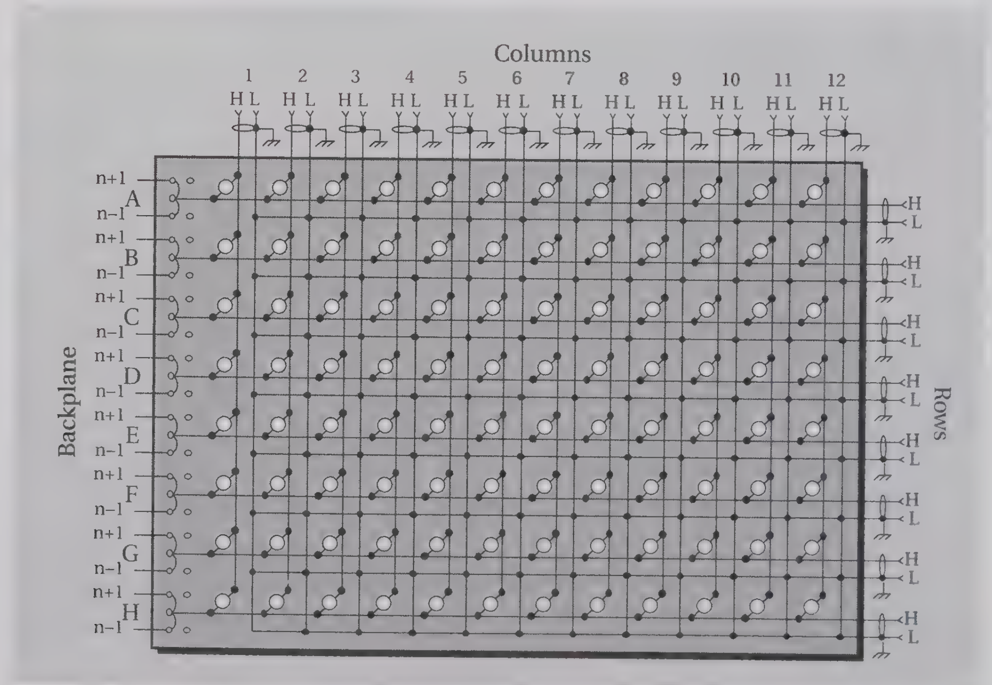
RELAY DRIVE CURRENT (per crosspoint): 20mA.

RELAY SETTLING TIME: <15msec..

ENVIRONMENT:
- **Operating:** 0° to 50°C, up to 35°C at 70% R.H.
- **Storage:** –25° to 65°C.

ACCESSORIES AVAILABLE:

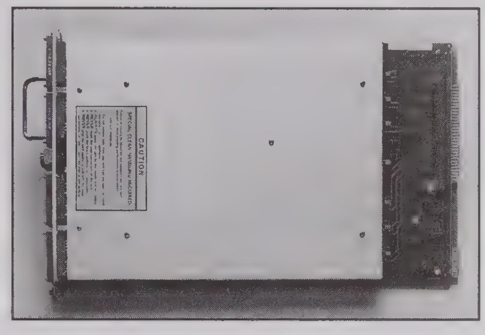
7051-2:	BNC to BNC Cable, 0.6m (2 ft.)
7051-5:	BNC to BNC Cable, 1.5m (5 ft.)
7754-3:	BNC to Alligator Cable, 0.9m (3 ft.)
7755:	50Ω Feed-Through Terminator



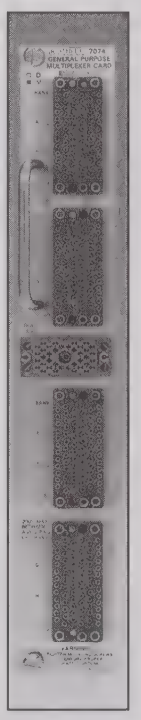
Eight 1×12 General Purpose Multiplexer Cards

The Models 7074-D and 7074-M consist of eight banks of independent 1×12 multiplexer switching. Each bank has three switched circuits (Hi, Lo, Guard) and is connected through jumpers on the switching card to one of eight General Purpose signal paths which provide automatic interconnect between switching cards. Jumpers may be removed to isolate any bank of switching or repositioned to cascade banks into longer switching configurations (1×24; 1×36; dual 1×48; 1×96; etc.). Or banks may be connected in a tree configuration for improved isolation.

Channel inputs of the multiplexer card are through four 75 pin mass terminated connectors. The corresponding cable accessory 7074-MTC is constructed with 24 sets of shielded twisted pair circuits for excellent noise immunity and electrical separation. Connections to the general purpose analog backplane can be accessed through jumpers on the multiplex card or by external connection through the mass terminated row connector provided.



- **7074-D: Dry reed contacts**
- **7074-M: Mercury wetted contacts**
- **3-pole Form A switching (HI, LO, GUARD)**
- **200V, 1A signal levels**



USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME
This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**

MULTIPLEX CONFIGURATION: Eight 1×12 banks. Adjacent banks can be connected together. Jumpers can be removed to isolate any bank from the backplane.

CONTACT CONFIGURATION: 3 pole Form A (HI, LO, GUARD).

CONNECTOR TYPE: Four 75 pin connectors for bank connections, one 38 pin connector for row connections.

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

OFFSET CURRENT: <100pA.

ISOLATION:
Bank: $>10^{10}\Omega$, <10pF.
Channel: $>10^{10}\Omega$, <10pF.
Differential:
Configured as a 1×12: $>10^{9}\Omega$, 55pF nominal.
Common Mode:
Configured as a 1×12: $>10^{9}\Omega$, 300pF nominal.

CROSSTALK:
Bank: <–55dB at 1MHz, 50Ω load.
Channel: <–55dB at 1MHz, 50Ω load.

	7074-D Dry Reed	7074-M Mercury Wetted
CONTACT LIFE:		
Cold Switching:	10^8 closures	10^9 closures
At Maximum Signal Levels:	10^5 closures	10^8 closures
CONTACT POTENTIAL: (per contact pair, <1 minute after actuation):	<5 µV	<10 µV
CHANNEL RESISTANCE:		
Initial:	<0.6 Ω	<0.6 Ω
At End of Contact Life:	<1.6 Ω	<0.7 Ω
RELAY DRIVE CURRENT: (per relay)	15 mA	50 mA

INSERTION LOSS (1MHz, 50Ω source, 50Ω load):
Configured as a 1×12: 0.1dB typical.

3dB BANDWIDTH (50Ω load):
Configured as a 1×12: 5MHz typical.

RELAY SETTLING TIME: <3msec.

ENVIRONMENT: Operating: 0° to 50°C, up to 35°C @ 70% R.H. **Storage:** –25° to 65°C.

ACCESSORIES SUPPLIED: 8 spare backplane jumpers.

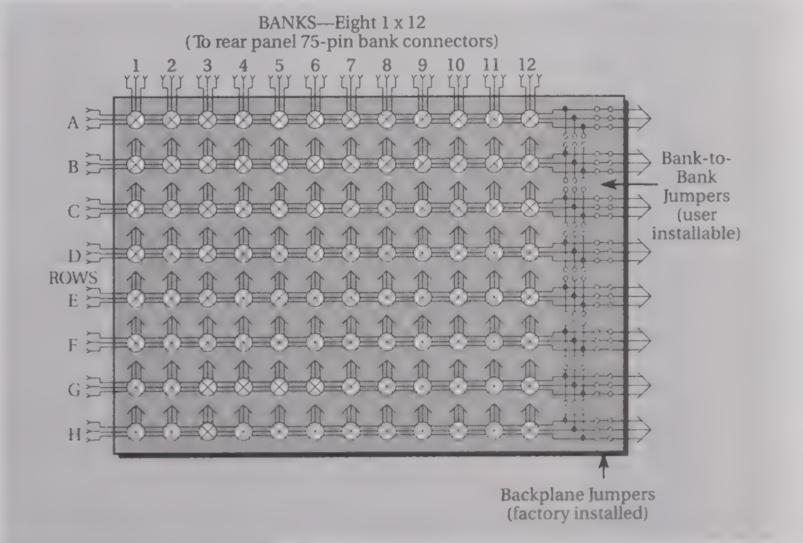
ACCESSORIES AVAILABLE:

Bank Connector Accessories:

7074-CIT:	Contact Extraction Tool
7074-HCT:	Hand Crimping Tool
7074-KIT:	Mass Terminated Plug with Contacts
7074-MTC-20:	Mass Terminated Cable Assembly, 6m(20 ft.)
7074-MTR:	Mass Terminated Receptacle with Contacts
7074-RTC:	Relay Test Shorting Connector

Row Connector Accessories:

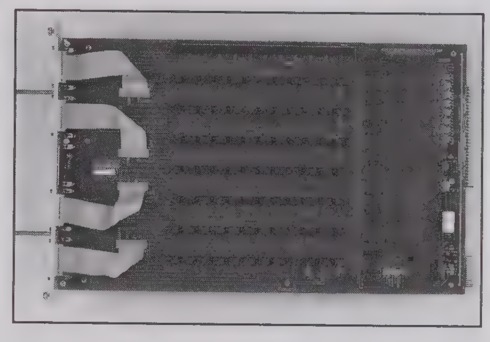
7078-CIT:	Contact Insertion and Extraction Tools
7078-HCT:	Hand Crimping Tool
7078-KIT:	Mass Terminated Plug with Contacts
7078-MTC-5:	Mass Terminated Cable Assembly, 1.5m (5 ft.)
7078-MTC-20:	Mass Terminated Cable Assembly, 6m (20 ft.)
7078-MTR:	Mass Terminated Receptacle with Contacts


BANKS—Eight 1 x 12
(To rear panel 75-pin bank connectors)
1
2
3
4
5
6
7
8
9
10
11
12
A
B
C
D
ROWS
E
F
G
H
Bank-to-Bank Jumpers (user installable)
Backplane Jumpers (factory installed)

7075 Eight 1×12, 2-Pole Multiplexer Card

- Low cost
- <5µV voltage offset
- <100pA offset current
- 30MHz bandwidth
- 110V, 1A signal levels
- Uses standard 25-pin D connectors

The Model 7075 is a general purpose multiplex switching card that consists of eight banks of independent 1×12 multiplexer switching. Each bank has two switched circuits (HI and GUARD). The row is connected through jumpers on the card to the general purpose analog backplane in the Model 707 switching mainframe. This provides the interconnect between cards for multiplexer expansion (1×24, 1×36, etc.). Jumpers may be removed to isolate any bank. A single card can be expanded to 1×96 by reconfiguring the supplied bank-to-bank jumpers. Eight 25-pin D connectors are provided for bank connections and one for row connection.



USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call:
1-800-552-1115 (U.S. only).

MULTIPLEX CONFIGURATION: Eight 1 × 12 banks. Adjacent banks can be connected together. Jumpers can be removed to isolate any bank from the backplane.

CONTACT CONFIGURATION: 2 pole Form A (HI, GUARD).

CONNECTOR TYPE: 25-pin subminiature D connector, eight for bank connection, one for row connection.

MAXIMUM SIGNAL LEVEL:
- **DC Signals:** 110V DC pin to pin, 1A switched, 30VA (resistive load).
- **AC Signals:** 175V AC peak pin to pin, 1A switched, 60VA (resistive load).

COMMON MODE VOLTAGE: 110V DC, 175V AC peak pin-to-pin or pin-to-chassis.

CONTACT LIFE:
- **Cold Switching:** 10^8 closures.
- **At Maximum Signal Level:** 10^5 closures.

CHANNEL RESISTANCE (per conductor): <0.50Ω initial, <1.5Ω at end of contact life.

CONTACT POTENTIAL: <5µV per contact pair (HI to GUARD).

OFFSET CURRENT: <100pA.

ISOLATION:
- **Bank:** $>10^{10}\Omega$, <3pF.
- **Channel:** $>10^{10}\Omega$, <5pF.
- **Differential:** Configured as 1×12: $>10^{9}\Omega$, <100pF nominal.
  Configured as 1×96: $>10^{8}\Omega$, <600pF nominal.
- **Common Mode:** Configured as 1×12: $>10^{9}\Omega$, <165pF nominal.
  Configured as 1×96: $>10^{8}\Omega$, <700pF nominal.

CROSSTALK (1MHz, 50Ω load):
- **Bank:** <–60dB.
- **Channel:** <–60dB.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.1dB typical.

3dB BANDWIDTH (50Ω load):
- Configured as 1×12: 30MHz typical.
- Configured as 1×96: 2.5MHz typical.

RELAY DRIVE CURRENT (per relay): 28mA.

RELAY SETTLING TIME: <3ms.

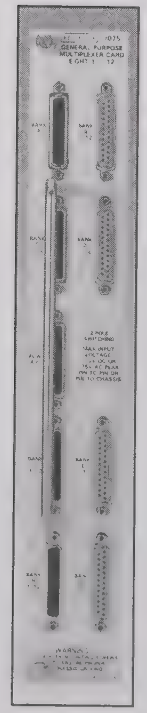
ENVIRONMENT:
- **Operating:** 0° to 50°C, up to 35°C at 70% R.H.
- **Storage:** –25° to 65°C.

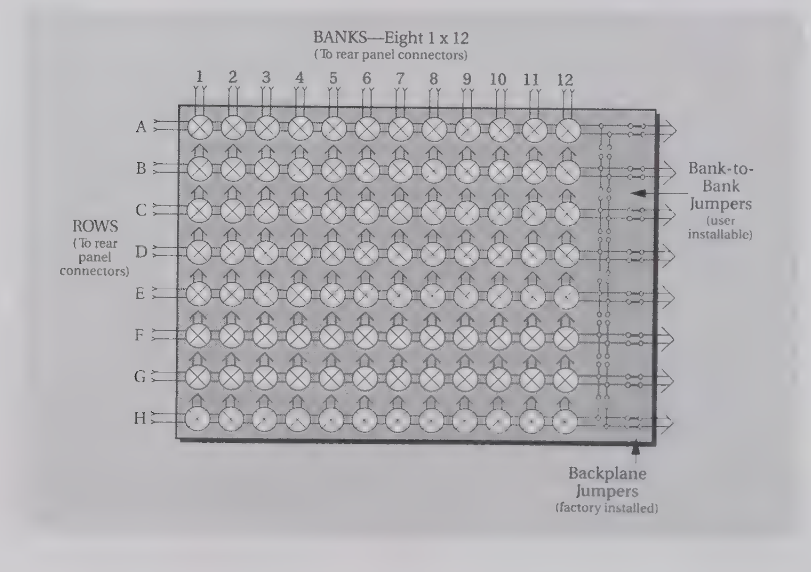
ACCESSORY SUPPLIED: Jumpers for multiplexer expansion.

ACCESSORIES AVAILABLE:

7076-RMTC	High Isolation Row Cable Assembly, 3m (10 ft.)
7076-CMTC	High Isolation Column/Bank Cable Assembly, 3m (10 ft.)
7075-MTC*	Row/Column/Bank Standard Cable Assembly, 3m (10 ft.)

*Standard cable can be used for either row or column connection.





Dual 4×12, 2-Pole Matrix Card

The Model 7076 is a general purpose matrix switching card that consists of two independent 4×12 switching matrices. Each matrix has two switched circuits (HI and GUARD). The four row signal paths are connected through jumpers to the general purpose analog backplane in the Model 707 switching mainframe. This provides the interconnect between cards for column expansion (4×24, 4×36 etc.). The jumpers may be removed to isolate any matrix. The columns of the two matrices on each card may be tied together with on-card jumpers for expansion to an 8×12 matrix. Connections to the matrix are through standard 25-pin D connectors for mass termination. There are two column connectors, one for each bank, and one row connector.

- **Low cost**
- **<5µV voltage offset**
- **<100pA offset current**
- **15MHz bandwidth**
- **110V, 1A signal levels**
- **Uses standard 25-pin D connectors**

MATRIX CONFIGURATION: Dual 4 rows by 12 columns. Also configurable as 8 rows by 12 columns. Jumpers can be removed to isolate any row from the backplane.

CROSSPOINT CONFIGURATION: 2 pole Form A (HI, GUARD).

CONNECTOR TYPE: 25-pin subminiature D connector, two for column connection, one for row connection.

MAXIMUM SIGNAL LEVEL:
  DC Signals: 110V DC, 1A switched, 30VA (resistive load).
  AC Signals: 175V AC peak, 1A switched, 62.5VA (resistive load).

COMMON MODE VOLTAGE: 110V DC, 175V AC peak pin-to-pin or pin-to-chassis.

CONTACT LIFE:
  Cold Switching: 10^8 closures.
  At Maximum Signal Level: 10^5 closures.

PATH RESISTANCE (per conductor): <0.50Ω initial, <1.5Ω at end of contact life.

CONTACT POTENTIAL: <5µV per crosspoint (HI to GUARD).

OFFSET CURRENT: <100pA.

ISOLATION:
  Path: $>10^{10}\Omega$, <5pF.
  Differential: $>10^{9}\Omega$, 120pF nominal.
  Common Mode: $>10^{9}\Omega$, 200pF nominal.

CROSSTALK (1MHz, 50Ω load): <–50dB.

INSERTION LOSS (1MHz, 50Ω source, 50Ω load): 0.05dB typical.

3dB BANDWIDTH (50Ω load): 15MHz typical.

RELAY DRIVE CURRENT (per crosspoint): 28mA.

RELAY SETTLING TIME: <3ms.

ENVIRONMENT:
  Operating: 0° to 50°C, up to 35°C at 70% R.H.
  Storage: –25° to 65°C.

ACCESSORY SUPPLIED: Jumpers for multiplexer expansion.

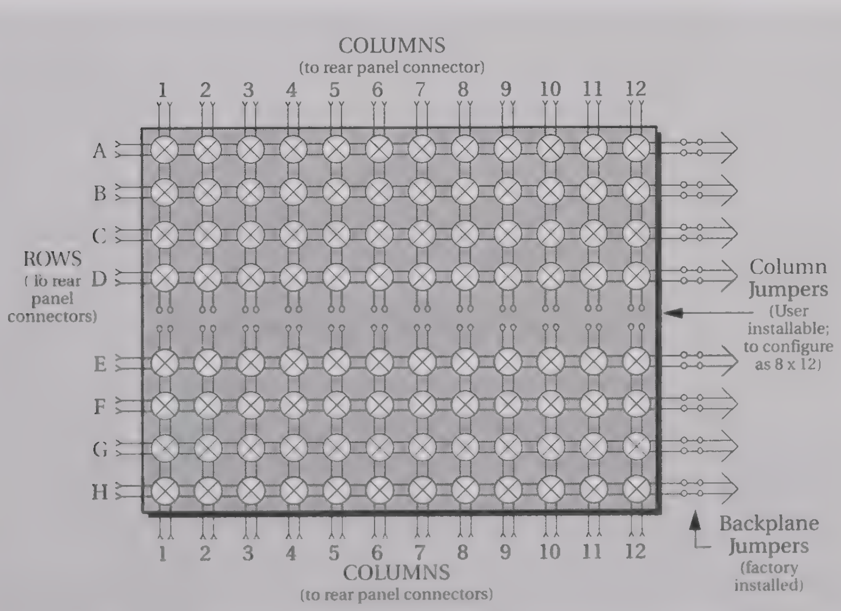
ACCESSORIES AVAILABLE:

7076-RMTC	High Isolation Row Cable Assembly, 3m (10 ft.)
7076-CMTC	High Isolation Column/Bank Cable Assembly, 3m (10 ft.)
7075-MTC*	Row/Column/Bank Standard Cable Assembly, 3m (10 ft.)

*Standard cable can be used for either row or column connection.

USE WITH MODEL 707 SWITCHING MATRIX MAINFRAME

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call: **1-800-552-1115 (U.S. only).**


COLUMNS
(to rear panel connector)
1
2
3
4
5
6
7
8
9
10
11
12
A
B
C
D
E
F
G
H
ROWS
(to rear panel connectors)
Column Jumpers
(User installable; to configure as 8 x 12)
Backplane Jumpers
(factory installed)
COLUMNS
(to rear panel connectors)

Selector Guide 140
Technical Data 142

213
Quad Voltage Source......................................144
220
Programmable Current Source 146
230
Programmable Voltage Source 146
224
Programmable Current Source 148
228A
Programmable Current/Voltage Source 149
247
High Voltage Supply 151
261
Picoampere Current Source 152
263
Calibrator/Source 153

Sources

Sources Selector Guide

MODEL	213	220	224	228A	230	236	237
Page	144	146	148	149	146	84	84
Current Source		•	•	•		•	•
Voltage Source	•			•	•	•	•
Sink		•	•	•	•	•	•
CURRENT OUTPUT							
From		±500 fA	±5 nA	±100 µA		±100 fA	±100 fA
To		±101 mA	±101 mA	±10 A		±100 mA	±100 mA
VOLTAGE OUTPUT							
From	250 µV			±1 mV	±50 µV	±100 µV	±100 µV
To	10.2375 V			±101 V	±101 V	±110 V	±1100 V
POWER OUTPUT							
		10 W	10 W	100 W	10 W	11 W	11 W
CURRENT LIMIT							
				100 µA to 10 A	2, 20, and 100 mA	1 pA to 100 mA	1 pA to 100 mA
VOLTAGE LIMIT							
		1V to 105V	1V to 105V	1mV to 101V		1mV to 110V	1mV to 1100V
ACCURACY (±SETTING)							
I				0.10%		0.05%	0.05%
V	0.05%	0.05%	0.05%	0.10%	0.05%	0.03%	0.03%
R							
Q							
FEATURES							
Programming	IEEE-488 included	IEEE-488 included	IEEE-488 option 2243	IEEE-488 included	IEEE-488 included	IEEE-488 included	IEEE-488 included
Memory	8192 pt.	100 pt.		100 pt.	100 pt.	1000 pt.	1000 pt.
Trigger		In/Out	In/Out	In/Out	In/Out	In/Out	In/Out
Remote Sense				•	•	•	•
Guard		•	•			•	•
Digital I/O	8 In/8 Out	4 In/4 Out	4 In/4 Out		4 In/4 Out		
Other	Quad voltage source			External modulation		Source/measure capability. Pulse mode. High speed. Built-in waveforms.	

Selector Guide

238	247	261	263	487	617	MODEL
84	151	152	153	60	53	Page
•		•	•			Current Source
•	•		•	•	•	Voltage Source
•						Sink
						CURRENT OUTPUT
±100 fA		±10 fA	±10 fA			From
±1 A		±10 µA	±20 mA			To
						VOLTAGE OUTPUT
±100 µV	±1.5 V		±5 µV	±1 mV	±50 mV	From
±110 V	±3000 V		±20 V	±505 V	102 V	To
						POWER OUTPUT
15 W	18 W	100 µW		1.25 W	200 mW	
						CURRENT LIMIT
1 pA to 100 mA	6 mA fixed			25 µA or 2.5 mA	2 mA fixed	
						VOLTAGE LIMIT
1mV to 110V		10mV-11V				
						ACCURACY—SETTING
0.05%			0.03%			I
0.033%	0.25%	0.50%	0.02%	0.1%	0.20%	V
			0.02%			R
			0.10%			Q
						FEATURES
IEEE-488 included			IEEE-488 included	IEEE-488 included	IEEE-488 included	Programming
1000 pt.				512 pt.	100 pt.	Memory
In/Out				In/Out	In/Out	Trigger
•						Remote Sense
•			•		•	Guard
						Digital I/O
Source/measure capability. Pulse mode. High speed. Built-in waveforms.	High voltage	pA calibrator	Calibrate/ source: I, V, R, Q	Picoammeter/ source. V/I measurements.	Electrometer/ source. V/I measurements.	Other

Technical Data

DC sources are fundamental to electronic circuits and devices. Their applications are varied but include:

DC Power: Circuit bias and operation.

DC Signal: Semiconductor parametric test; setting levels; reference and comparison; calibration; threshold detection; particle or beam deflection

Active Load: Sink power from device under test.

Keithley sources are more than just power supplies; they are DC instruments designed to supply precision voltage or current. Sources deliver performance over and above power supplies in one or more of these characteristics:

- Dynamic range of output
- Sensitivity
- Power source or sink
- Programmability
- Output impedance and isolation
- Transient response

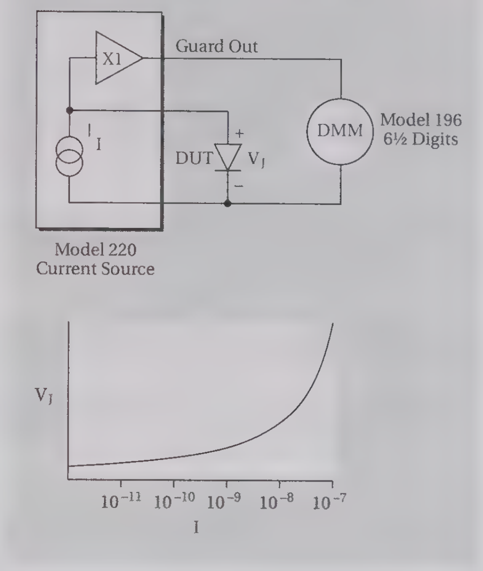
Dynamic Range is important when testing semiconductor devices or a wide variety of diverse DUTs (see **Figure 1**). Values required for testing may span several decades of voltage or current. For the best accuracy and regulation of the output, it is important that the programmed value be greater than 20% of range.

All Keithley sources have multiple output ranges covering as many as 9 decades, as in the case of the Model 220 Current Source (page 146). This means that the optimum range for test accuracy and precision can be selected. Dynamic range provides flexibility to satisfy your present and future test requirements, and minimizes the need for multiple instruments.

Sensitivity

When sensitivity (a small signal) is required, Keithley sources satisfy the need. Currents as low as 10 femtoamps and voltages down to 5 microvolts can be programmed under computer control.

FIGURE 1: Semiconductor Parametric Test



Source or Sink

Bipolar outputs allow setting of either positive or negative values on most Keithley sources. This bipolar operation simplifies test procedures and system design by eliminating the need for external switching or operator intervention to reverse the polarity of the output leads. In addition, these sources can act as an active load to a device under test such as a power supply, battery, or solar cell. The 4-quadrant capability (see **Figure 2a**) is ideal for charge/discharge cycle testing of batteries, applications in corrosion studies, and precision electroplating.

The power output capacity of Keithley sources ranges up to 100W in the Model 228A (page 149). Power sink (dissipation) capacity equals the source capability, and is rated over the entire operating temperature range.

Programmability

System performance through an IEEE-488 interface is available on most Keithley sources (see Selector Guide). All front panel controls and settings are programmable, and a number of convenience capabilities such as hardware triggers, programmable delays, and internal program memory simplifies system integration.

FIGURE 2A: Four-Quadrant Operation

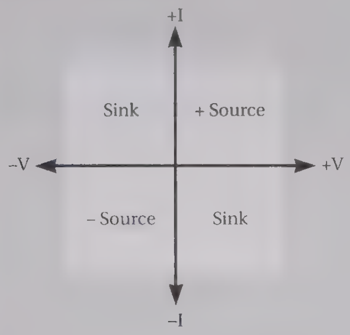
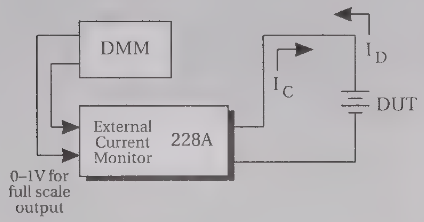


FIGURE 2B: Measuring Charge/Discharge Characteristics of Batteries



Output Impedance

Keithley sources satisfy your need for near ideal output characteristics in critical applications. These sources go beyond power supply standards in achieving high isolation, low output offsets, and near ideal source impedance to assure minimum interaction and source effect in the test application.

For example, a guarded output (**Figure 1**) permits the use of a standard system DMM without affecting the $10^{14}\Omega$ output impedance of the Model 220 current source. Error contribution of the voltage follower amplifier is less than ±1mV. When used with a Model 6167 guarded input adapter, the guarded output also speeds circuit settling by compensating for shunt resistance and capacitance in the test cables.

Remote Sensing compensates for series resistance in the interconnect cabling. This assures that the full programmed voltage value is seen by the DUT.

Isolation

The outputs of Keithley sources are electrically isolated and can be floated above power line ground. This helps reduce the effects of ground loops, and can be used to achieve higher terminal voltages.

Transient Response

Keithley sources have been optimized for fast response. Most sources settle within milliseconds in response to changes in load or output value, and outputs are stable under a variety of load conditions.

Other Conveniences

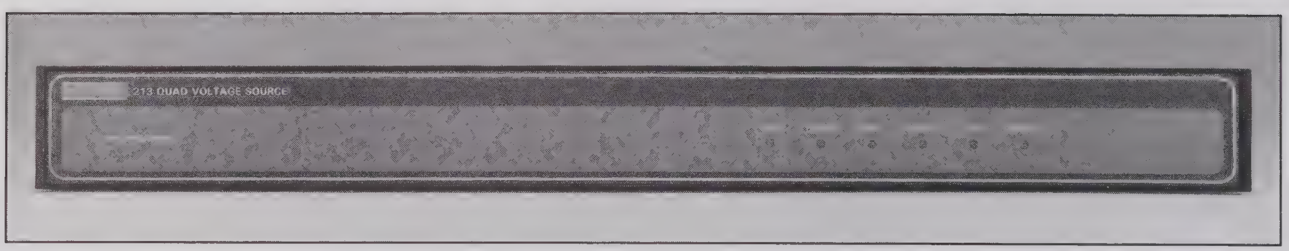
- **Digital I/O:** Keithley programmable sources include several built-in lines of TTL-compatible digital I/O. This added capability, which can be programmed and read back over the IEEE-488 bus, can be used for monitoring test system status or actuating external circuits.
- **Program Memory:** Some Keithley sources have memories that can be programmed with a sequence of output values. Once programmed, the sequence can be repeated in step fashion by issuing a trigger command to the source. This minimizes bus activity and improves system speed. The Model 213 has an 8192 sample waveform buffer to store waveforms for each of the 4 outputs.

Source Application Areas

Semiconductor Parametric Analysis
Materials Research
Solar Cell Testing
Battery Charge/Discharge Characteristics
Relay and Resistive Component Testing
Photomultiplier Tubes
Calibration of Low Current Instruments
Hall Effect
Programmable Load
Breakdown and Insulation Resistance Test
...and many more.

Keithley manufactures a broad range of compatible measurement and switching instruments. Check other sections in this catalog for your complete instrumentation needs.

213 Quad Voltage Source



- **Provides GPIB-controlled voltage bias**
- **Autoranging or programmable ±1V, ±5V, or ±10V ranges**
- **Four independent and stackable 12-bit voltage sources**
- **10mA output current per channel**
- **Quick-disconnect cable**

IEEE-488

[illegible]

213
Quad Voltage Source with Analog Output Connector

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

[illegible]

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.4 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

CONNECTORS

213-CON	Analog Output Connector
213-RBN-2	Card Edge Connector with 2m (6.2 ft.) ribbon cable

See page 163 for descriptions of all accessories.

Description

The Model 213 Quad Voltage Source (QVS) is a convenient and cost-effective instrument for adding voltage bias to GPIB test systems. Each of four fully independent channels provides up to ±10V at 10mA of voltage bias. 12-bit source programmability provides voltage resolution down to 250µV/bit, 1.25mV/bit, and 2.5mV/bit for the ±1V, ±5V, and ±10V ranges, respectively.

Applications

The 213 QVS was designed for biasing devices in multi-pin test systems, such as semiconductor characterization. It complements SMUs and other precision sources and meters.

Common biasing applications include typical or worst case test conditions on analog or digital input pins, and "reverse biasing" on unused pins or adjacent wafer-level devices to isolate them from the measurement.

Digital I/O with 100mA Drive Current

The 213 QVS also provides 8 bits each of TTL compatible digital input and output on a card edge connector for easy control and monitoring of system status. The digital outputs have an open collector drive with 100mA capability, for driving low level relays and similar applications.

Convenient Quick Disconnect

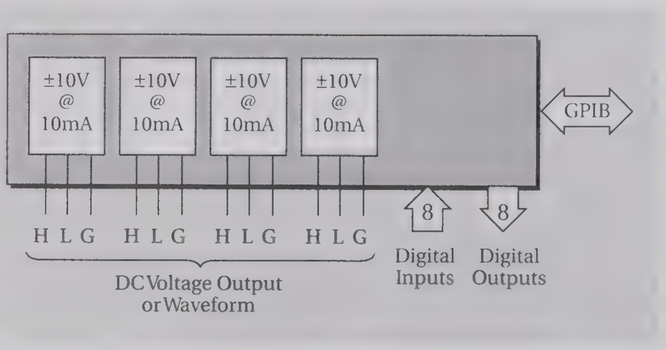
Analog connection is made through one 12-pin quick disconnect on the rear panel. High, Low, and Chassis Ground screw terminals are provided on each channel for connection flexibility.

Fast Waveform Buffers

An 8192 sample waveform buffer allows the user to store waveforms for each channel with a maximum update rate of 1ms per sample. Each waveform can be output in sequence based on either a periodic interval or one of three trigger conditions: an external trigger, a trigger command, or the Group Execute Trigger (GET) bus command. Each port can be triggered independently via any of the trigger conditions.

Automatic Calibration

The 213 QVS is calibrated entirely from the GPIB bus—no mechanical adjustments are required. Calibration constants for each channel are stored in the unit's non-volatile memory. Calibration can also be performed without a computer by connecting the 213 QVS to a Keithley 199/1992 DMM with Scanner. In this calibration mode, the 213 becomes the GPIB system controller and uses readings from the 199 to automatically calculate its calibration constants.



Quad Voltage Source

SPECIFICATIONS

QUAD VOLTAGE SOURCE: Sources voltage from four independent, isolated ports. Includes 8-bit digital I/O port.

FUNCTION: Can be used as a constant DC source or as a voltage waveform generator.

INTERNAL BUFFER: An 8192-location internal buffer is used to store values for waveform generation.

CONTROL MODES: Four control modes may be chosen by the user:

Direct: Output changes upon execution of the "V" device dependent command.

Indirect: Output changes after receiving an external trigger.

Stepped: Step through internal buffer under control of external triggers.

Waveform: Output voltage waveform from buffer, under control of an internal time base.

NUMBER OF WAVEFORM CYCLES: The number of cycles through the buffer in the Waveform Control Mode is user selectable, 1 to 65535 or continuous.

SYNCHRONIZATION OF PORTS: The ports can be forced to execute their voltage waveforms in a synchronized manner.

WAVEFORM STEP INTERVAL: 1ms to 65535ms.

TRIGGER AND SRQ: IEEE-488 bus or rear panel card-edge.

DIGITAL I/O: 8 TTL compatible level sensitive inputs. 8 outputs, internally selectable TTL compatible or open collector with 100mA drive and 50V withstand capability (for driving relays or other devices from an external voltage supply).

VOLTAGE

RANGE	MAXIMUM OUTPUT	STEP SIZE	ACCURACY 18°-28°C [illegible]
1 V	±1.02375 V	250 μV	±(0.05% + 1 mV)
5 V	±5.11875 V	1.25 mV	±(0.05% + 3 mV)
10 V	±10.2375 V	2.5 mV	±(0.05% + 10 mV)

TEMPERATURE COEFFICIENT OF ACCURACY (0°-18°C & 28°-50°C): ±(0.002% of setting + 100μV)/°C.

RANGING: Autorange or select one of three fixed ranges.

DC OUTPUT CURRENT: 10mA maximum.

OUTPUT RESISTANCE: <500mΩ, typical.

NOISE (p-p, typical):

RANGE	0.1-10Hz
1 V	<5ppm of range
5 V	<3ppm of range
10 V	<3ppm of range

WIDEBAND NOISE (p-p, typical): 0.1 to 20MHz, 8mV.

SETTLING TIME (typical): 1000s. to rated accuracy into a 1kΩ load.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: SDC, DCL, GET, UNL, UNT, SPE, SPD, MTA, MLA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T4, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0 (C28 during calibration), E1.

PROGRAMMABLE FUNCTIONS: Port select, output voltage, control mode, autorange enable, range select, waveform step interval, number of cycles, offset calibration, gain calibration, buffer allocation, buffer data, buffer location pointers, command trigger, trigger masking, SRQ masking, system defaults, digital output, EOI, IEEE-488 output terminator, IEEE-488 output format, system status output, system test, error query.

IEEE-488 address is set manually from the rear panel.

EXECUTION SPEED

RESPONSE TO IEEE-488 COMMAND: <10ms typical.

TRIGGER LATENCY: 1-2ms typical (all three types of external triggering), trigger to output voltage change.

GENERAL

CHANNEL TO CHANNEL ISOLATION: 500V or 10^5V•Hz, whichever is less.

CHANNEL TO DIGITAL LOW ISOLATION: 500V or 10^5V•Hz, whichever is less.

CONNECTORS: **Outputs:** 12-pin quick disconnect.
Digital I/O: 20-pin card edge.

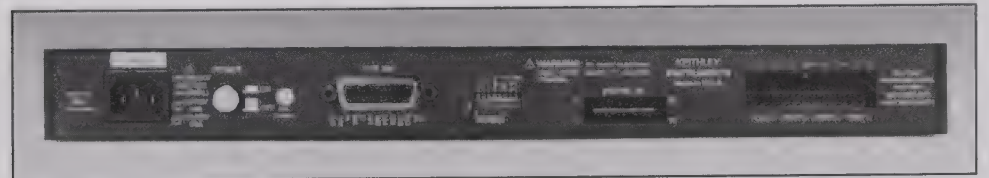
ENVIRONMENT:
Operating: 0°–50°C; 0–70% relative humidity to 35°C. Linearly derate relative humidity 3%/°C, 35°–50°C.
Storage: –25° to 65°C.

WARM-UP: One hour to rated accuracy.

POWER: 90–125 or 180–250V AC (internally switch selectable); 50-60 Hz, 70VA max.

DIMENSIONS, WEIGHT: 425mm wide × 45mm high × 309mm deep (16¾ in. × 1¾ in. × 12 in.). Net weight 3.52kg (7.75 lbs.).

ACCESSORIES SUPPLIED:
Instruction manual
213-CON Analog Output Connector



Programmable Sources

MODEL 220 CURRENT SOURCE

- **±0.5pA to ±101mA DC output**
- **$10^{14}\Omega$ output resistance**
- **±1V to ±105V programmable V-LIMIT**

MODEL 230 VOLTAGE SOURCE

- **±50μV to ±101V DC output**
- **±2mA, ±20mA, ±100mA programmable I-LIMIT**
- **Remote sensing**

IEEE-488

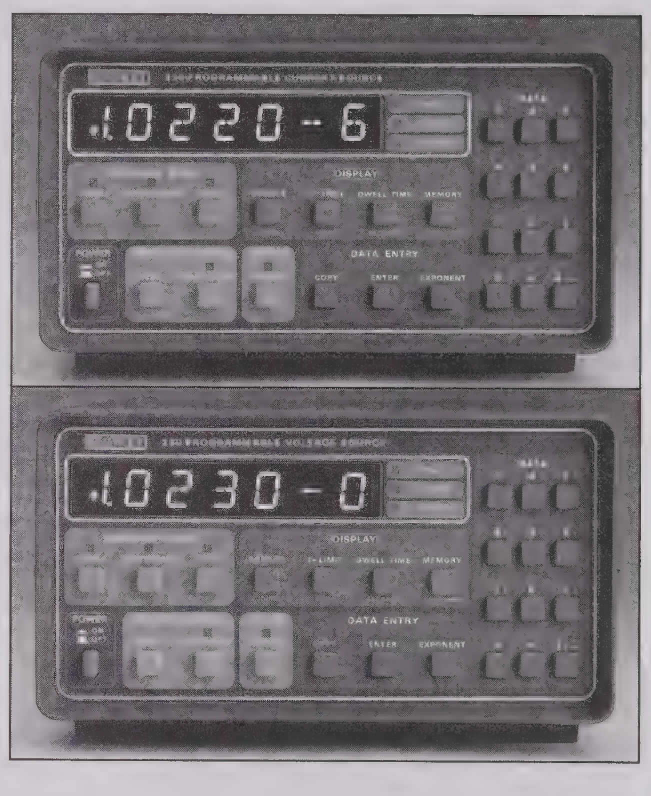
[illegible]

220
Programmable Current Source with instruction manual, programming guide, Model 6011 Input Leads, 1.5m (5 ft.), Triax to Clips

230
Programmable Voltage Source with instruction manual and programming guide

230-1
Programmable Voltage Source with instruction manual and programming guide (for Model 82, 82-DOS Simultaneous CV Systems)

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.



The demand on researchers, designers, and evaluation engineers for better device characterization has generated a widespread need for programmable, low-level DC sources. And, as an experienced manufacturer of automatic wafer measuring equipment, Keithley knows the importance to the user of instrument compatibility and ease of system integration. The 220 programmable current source and 230 programmable voltage source find major applications in semiconductor characterization, materials research, and ATE systems.

Both models incorporate a 100-step, programmable memory buffer, useful in applications where either a fixed number of outputs is repeated, or a complex waveform of discrete steps must be generated.

In system applications, the buffer can be loaded through the bus and the 220 or 230 can be commanded to sequence through memory while the controller is busy on other tasks.

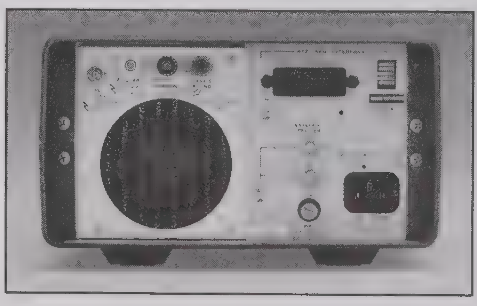
The TRIGGER IN/OUT feature, when used in the STEP mode, allows the source to synchronize the measurements of other instruments such as the 619 electrometer/multimeter. The TRIGGER OUT occurs after the completion of dwell time; TRIGGER IN causes the 220 or 230 to advance to its next program step. This provides the capability to perform a preset source measurement without a computer.

Four TTL-compatible input and output (I/O) lines are provided on each model to receive and generate system commands. In a typical application, a source can be programmed to generate an SRQ (service request) to the controller if a system element such as a foot pedal switch, mechanical stop, or over-temperature condition is detected.

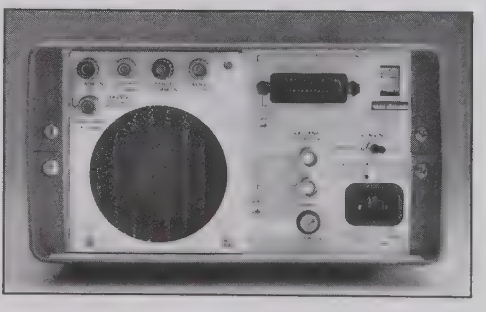
The I/O can provide a means for the customer to shut down the power supply for safety in a system environment. Digital I/O is an example of the convenience features that make the Models 220 and 230 easy to use in your test system.

The **230-1** is a special version of the 230 with the necessary connectors for compatibility with the Model 82 Simultaneous C-V Systems.

220 rear panel



230 rear panel



Programmable Sources 220,230

MODEL 220 CURRENT SOURCE

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) 18°–28°C	STEP SIZE	TEMPERATURE COEFFICIENT/°C 0°–18°C & 28°–50°C	NOISE (pk-pk of range)	3dB BANDWIDTH
100 mA	±101.00 mA	0.1 % + 50 µA	50 µA	0.01 % + 2 µA	100 ppm	0.1 Hz to 30 kHz
10 mA	±19.995 mA	0.05% + 10 µA	5 µA	0.005% + 200 nA	100 ppm	0.1 Hz to 100 Hz
1 mA	±1.9995 mA	0.05% + 1 µA	500 nA	0.005% + 20 nA	100 ppm	0.1 Hz to 100 Hz
100 µA	±199.95 µA	0.05% + 100 nA	50 nA	0.005% + 2 nA	100 ppm	0.1 Hz to 100 Hz
10 µA	±19.995 µA	0.05% + 10 nA	5 nA	0.005% + 200 pA	100 ppm	0.1 Hz to 100 Hz
1 µA	±1.9995 µA	0.1 % + 1 nA	500 pA	0.01 % + 20 pA	100 ppm	0.1 Hz to 100 Hz
100 nA	±199.95 nA	0.3 % + 100 pA	50 pA	0.02 % + 2 pA	100 ppm	0.1 Hz to 100 Hz
10 nA	±19.995 nA	0.3 % + 10 pA	5 pA	0.02 % + 200 f A	200 ppm	0.1 Hz to 10 Hz
1 nA	±1.9995 nA	0.4 % + 2 pA	500 f A	0.02 % + 200 f A	400 ppm	0.1 Hz to 10 Hz

OUTPUT RESISTANCE: $>10^{14}\Omega$.

OUTPUT CAPACITANCE: <20pF.

LINE REGULATION: <0.01% for AC power line changes within specified limits.

VOLTAGE LIMIT: Bipolar, 1 to 105 volts in 1V programmable steps.

RESPONSE TIME: <3ms to within 0.1% of programmed change.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy following any change in compliance voltage.

GUARD OUTPUT:
Maximum Load Capacitance: 10nF.
Maximum Load Current: Absolute total (Output + Guard) not to exceed 105mA.
Accuracy: ±1mV (excluding output lead voltage drop).

PROGRAM MEMORY:
Number of Locations: 100.
Range of Dwell Times: 3ms to 999.9s.
Accuracy of Dwell Time: ±(0.05%+200µs).

OUTPUT LOAD: Output load must be non-inductive.

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Teflon® insulated 2-lug triax connector (Specialty Connector #30JR121-1) for output; five-way binding posts for GUARD, OUTPUT COMMON, and CHASSIS; BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT, Amphenol or Cinch Series 87 IEEE and printed circuit digital I/O port. All connections on rear panel.

MODEL 230 VOLTAGE SOURCE

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) 18°–28°C	STEP SIZE	TEMPERATURE COEFFICIENT/°C 0°–18°C & 28°–50°C
100 V	±101.00 V	0.05 % + 50 mV	50 mV	0.005% + 0.5 mV
10 V	±19.995 V	0.05 % + 10 mV	5 mV	0.005% + 100 µV
1 V	±1.9995 V	0.05 % + 1 mV	500 µV	0.005% + 25 µV
100 mV	±199.9 mV	0.075% + 300 µV	50 µV	0.01 % + 25 µV

MAXIMUM CURRENT LIMIT: ±100mA (–0, +20%).

SELECTABLE CURRENT LIMIT: ±100mA, ±20mA, ±2mA (–0, +20%).

LINE REGULATION: <0.01% for AC power line changes within specified limits.

NOISE: (150µV + 50ppm range) p-p, 0.1Hz to 300Hz; 5mV p-p, 0.1Hz to 300kHz. Specification applies for local sensing only, typical.

RESPONSE TIME: <3ms to within 0.1% of programmed change for Current Limit of at least 20mA.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy for Current Limit of at least 20mA.

OUTPUT IMPEDANCE:

SELECTED CURRENT LIMIT	OUTPUT IMPEDANCE
2 mA	1 mΩ + 10 mH
20 mA	1 mΩ + 2 mH
100 mA	1 mΩ + 1 mH

SENSING: Rear panel selectable REMOTE and LOCAL sensing.

REMOTE SENSING:
Maximum Lead Drop (per lead): 0.5V.
Maximum Sense Lead Resistance (per lead): 5Ω.

PROGRAM MEMORY:
Number of Locations: 100.
Range of Dwell Times: 3ms to 999.9s
Accuracy of Dwell Time: ±(0.05% + 200µs).

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Five-way binding posts for OUTPUT, OUTPUT SENSE, COMMON, COMMON SENSE, and CHASSIS GROUND; BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT. All connections on rear panel.

GENERAL (220, 230)

DISPLAY: 0.5 in. LED digits, 4½-digit signed mantissa, 1-digit signed exponent.

SYSTEMS COMPATIBILITY: IEEE-488-1978.

LIMIT INDICATIONS:
Model 220 (Voltage Limit): "V-LIMIT" LED will blink.
Model 230 (Current Limit): "I-LIMIT" LED will blink.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGE (OUTPUT or OUTPUT COMMON to CHASSIS): 250V rms, DC to 60Hz.

SELF TEST: Digital RAM, ROM, front panel LEDs upon power ON.

WARM-UP: 1 hour to rated accuracy.

POWER: 105–125 or 210–250V AC (internal switch selected), 50 or 60Hz, 60W maximum (80VA maximum). 90–105 or 180–210V AC operation available.

COOLING: Internal fan for forced air cooling.

ENVIRONMENTAL LIMITS: Operating: 0°–50°C; up to 35°C at 70% non-condensing relative humidity. **Storage:** –25° to 70°C.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.4kg (9 lbs. 11 oz.).

ACCESSORIES SUPPLIED (220): Model 6011 Triaxial Test Lead (3 ft.). **(220, 230):** Instruction manual, programming guide.

IEEE-488 BUS IMPLEMENTATION (220, 230)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

INTERNAL PROGRAMMABLE PARAMETERS: Display Mode, Output, Prefix Data Format, EOI, SRQ (including mask for over Limit), Program Mode, Range, Trigger Mode, Terminator Character, Inputs (Source, Limit, Dwell Time, 100-Point Memory Locations), Output Status, Digital Self Test.

DIGITAL I/O PORT: A separate I/O port consisting of four input and four output lines as well as common (IEEE-488) and +5V DC. Outputs will drive one TTL load. Inputs represent one TTL load. The 220 or 230 can be programmed to generate an "SRQ" upon any change in the four bit input data. Mating connector supplied.

ACCESSORIES AVAILABLE

TEST LEADS (220)

6011	Input Leads, 2-Slot Male Triax to Alligator Clips, 1.5m (5 ft.)
6011-10	Input Leads, 2-Slot Male Triax to Alligator Clips, 3m (10 ft.)

CABLES (220 & 230)

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.4 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
7024-3	Low Noise Triax Cable, 0.9m (3 ft.) (220 only)
7024-10	Low Noise Triax Cable, 3m (10 ft.) (220 only)

ADAPTERS (220)

6146	Triax Tee Adapter
6147	2-Slot Male Triax to Female BNC Adapter
6167	Guarded Input Adapter
6172	2-Slot Male to 3-Lug Female Triax Adapter

RACK MOUNT KITS (220 & 230)

1019A-1	Single Fixed Rack Kit
1019S-1	Single Slide Rack Kit
1019A-2	Dual Fixed Rack Kit
1019S-2	Dual Slide Rack Kit

See page 163 for descriptions of all accessories.

224 Programmable Current Source

- **±5nA to 101mA DC output**
- **$10^{12}\Omega$ output resistance**
- **Auto increment/decrement**
- **HI-LO limits for auto increment/decrement**
- **±1V to ±105V programmable V-LIMIT**

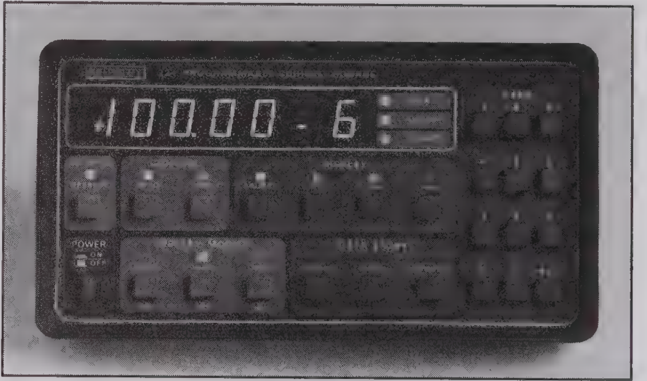
IEEE-488

ORDERING INFORMATION

224
Programmable Current Source with instruction manual and Model 6011 Input Leads, 1.5m (5 ft.), Triax to Clips

224/2243
Programmable Current Source with IEEE-488 interface, instruction manual and Model 6011 Input Leads, 1.5m (5 ft.), Triax to Clips

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**



The Model 224 programmable current source was designed for general purpose bench or system use. The INCREMENT/DECREMENT function is manual or automatic, and selectable dwell times provide stepped ramp capabilities.

The Model 2243 IEEE-488 option is field installable. It allows flexible programming including current, V-LIMIT, local lockout, service request masks, and serial polling. A digital I/O port on the IEEE-488 interface card provides four TTL-compatible input and output lines. The status of the I/O port can be interrogated and changed over the bus.

The AUTO function allows automatic incrementing or decrementing of the output. Time per step can be set from 50ms/step to 999.9s/step.

In some applications, it is necessary to limit the voltage across the device under test. The Model 224 offers compliance limit settings ranging from ±1V to ±105V in 1V steps. An SRQ on V-LIMIT can be programmed if the 2243 IEEE-488 option is installed. A blinking LED indicates V-LIMIT for bench operation.

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) [illegible]	[illegible]	TEMPERATURE COEFFICIENT [illegible]
100 mA	±101.00 mA	0.1 + 50 µA	50 µA	0.01 + 2 µA
10 mA	±19.995 mA	0.05 + 10 µA	5 µA	0.005 + 200 nA
1 mA	±1.9995 mA	0.05 + 1 µA	500 nA	0.005 + 20 nA
100 µA	±199.95 µA	0.05 + 100 nA	50 nA	0.005 + 2 nA
10 µA	±19.995 µA	0.05 + 10 nA	5 nA	0.005 + 200 pA

OUTPUT RESISTANCE: $>10^{12}\Omega$

OUTPUT CAPACITANCE: <20pF.

LINE REGULATION: <0.01% for AC power line changes within specified limits.

VOLTAGE LIMIT: Bipolar, 1 to 105V in 1V programmable steps.

RESPONSE TIME: <3ms to within 0.1% of programmed change.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy following any change in compliance voltage.

RANGE	[illegible]	[illegible]
100 mA	100 ppm	0.1 Hz to 30 kHz
10 µA to 10 mA	100 ppm	0.1 Hz to 100 Hz

GUARD OUTPUT:
Maximum Load Capacitance: 10nF.
Maximum Load Current: Absolute total (output + guard) ≤105mA.
Accuracy: ±1mV (excluding output lead voltage drop).

INCREMENT/DECREMENT: Automatic, manual or trigger modes.
Range of Dwell Times: 50ms to 999.9s.
Accuracy of Dwell Times: ±(0.05% + 20µs).
Step Size: Selected digit on a fixed range; min. size 0.1% of range.
Current Limit: Maximum is ±full scale on range selected.

OUTPUT LOAD: Output load must be non-inductive.

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Teflon® insulated 2-lug triax connector (Specialty Connector 30JR121-1) for output; five way binding posts for GUARD, OUTPUT COMMON and CHASSIS GROUND; BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT. All connections on rear panel.

ACCESSORIES AVAILABLE

TEST LEADS

6011	Input Leads, 2-Slot Male Triax to Alligator Clips, 1.5m (5 ft.)
6011-10	Input Leads, 2-Slot Male Triax to Alligator Clips, 3m (10 ft.)

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.4 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)

ADAPTERS

6146	Triax Tee Adapter
6147	2-Slot Male Triax to Female BNC Adapter
6167	Guarded Input Adapter
6172	2-Slot Male to 3-Lug Female Triax Adapter

RACK MOUNT KITS

1019A-1	Single Fixed Rack Kit
1019S-1	Single Slide Rack Kit
1019A-2	Dual Fixed Rack Kit
1019S-2	Dual Slide Rack Kit

See page 163 for descriptions of all accessories.

IEEE-488 BUS INTERFACE (Option 2243)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

INTERNAL PROGRAMMABLE PARAMETERS: Display Mode, Output, Prefix Data Format, EOI, SRQ (including mask for over V-Limit), Range, Terminator Character, Inputs (Source, V-Limit, Dwell Time), Output Status.

DIGITAL I/O PORT: A separate I/O port consisting of four input and four output lines as well as common (IEEE-488) and +5V DC. Outputs will drive one TTL load. Inputs represent one TTL load. The 224 can be programmed to generate an "SRQ" upon any change in the four bit input data. Mating connector supplied.

GENERAL

DISPLAY: 0.5 in. LED digits, 4½-digit signed mantissa, 1-digit signed exponent.

OVER VOLTAGE LIMIT INDICATION: "V-LIMIT" LED blinks.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGE (OUTPUT or OUTPUT COMMON to CHASSIS): 250V rms, DC to 60Hz.

SELF TEST: Digital RAM, ROM, & front panel LEDs at power ON.

WARM-UP: 1 hour to rated accuracy.

POWER: 105–125 or 210–250V AC (internal switch selected), 50 or 60Hz, 60W maximum (80VA maximum). 90–105 or 180–210V AC operation available.

COOLING: Internal fan for forced air cooling.

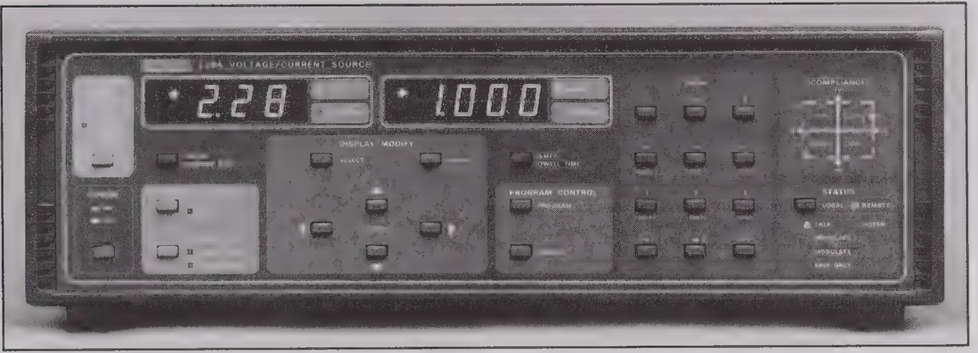
ENVIRONMENTAL LIMITS: Operating: 0°–50°C; up to 35°C at 70% non-condensing relative humidity. **Storage:** –25° to 70°C.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.5kg (9 lbs. 15 oz.).

ACCESSORIES SUPPLIED: Model 6011 Triaxial Test Lead (3 ft.), instruction manual.

Voltage/Current Source

228A



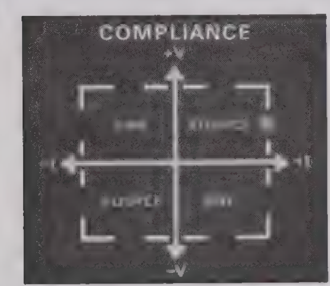
- 100 watt source or sink
- <1ms transient recovery
- Low noise
- Smooth range changes
- Built-in voltage and current monitors

IEEE-488

The Model 228A is a precision programmable source with the capacity to sink or source up to 100 watts. Six ranges accurately regulate voltage or current as determined by the load. And because it is two programmable sources in one (with built-in monitors), you get the flexibility for a broader range of test setups, without having to buy separate sources.

4-Quadrant Operation

The 228A is capable of bipolar source or sink up to a full 100 watts without derating, permitting it to act as a voltage or current supply or as an active load. Operating status is continuously shown on front panel LEDs.

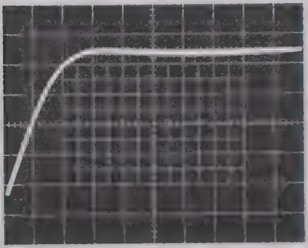


Front panel LEDs continuously display operating status.

The 228A's modulation input allows voltage programming. DC to 600Hz inputs can be used to vary the output within the full scale range of the source, simulate variable load conditions in sink, provide a power boost, or test power supply rejection.

Fast Response

Load transient recovery time is less than 1ms, without overshoot or oscillation.



Actual 228A transient response, 100V range @ 1A.

Vert.: 20V/div.

Horiz.: 0.2ms/div.

Voltage and Current Monitor

The output voltage and current are continuously monitored and displayed. These values can also be read back over the IEEE-488 bus, eliminating the need for separate measurement instruments.

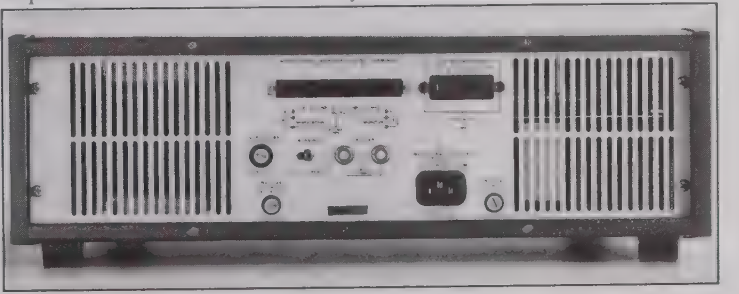
Remote sensing assures the full rated voltage under test, even when delivering high currents. And our unique safety disconnect design eliminates external terminal blocks and barrier strips.

Keithley's unique disconnect design assures safe setup and operation.

Fully Programmable

The IEEE-488 interface is standard with the 228A, and all front panel controls and capabilities are available over the bus. TRIGGER IN/OUT enables synchronization with other components in your test setup, and the programmable dwell time allows settling before TRIGGER OUT is issued.

The 228A checks its own operation and provides diagnostic error messages. An SRQ can be programmed to alert the system of many operating conditions. The internal 100-point memory retains programmed data through power down, brownout, or even a month or more in storage, and allows you to step through repetitive test sequences with minimal bus activity.



ORDERING INFORMATION

228A
Programmable Voltage/
Current Source with IEEE-488
Interface and 2286 Safety
Output Connector

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

2286	Safety Output Connector
RACK MOUNT KITS	
2288	Fixed Rack Mounting Kit
2289A	Slide Rack Mounting Kit
CABLES	
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)
7008-3	IEEE-488 Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Cable, 1.8m (6 ft.)

See page 163 for descriptions of all accessories.

228A Voltage/Current Source

CURRENT MONITOR OUTPUT

SCALE FACTOR: 1V = 100% of range.

ACCURACY: Same as constant current mode.

BANDWIDTH: 5kHz typical.

OUTPUT RESISTANCE: 10kΩ.

EXTERNAL MODULATION

INPUT RESISTANCE: 6.8kΩ.

SENSITIVITY: –10V increases magnitude of programmed output by 100% full scale; +10V decreases magnitude of programmed output by 100% full scale.

ACCURACY: 2% typical, DC to 60Hz.

MAXIMUM MODULATION: Modulation and programmed setting should not cause operation exceeding the range of 0 to 100% of full scale.

MODULATION FREQUENCY: 600Hz bandwidth.

IEEE-488 BUS IMPLEMENTATION (IEEE-488-1978)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Output (Operate or Standby), Range, Voltage, Current, Trigger Mode, Sink, Modulation (Voltage or Current), Display Mode, Output Prefix (data format on readback), SRQ Mask, EOI, Terminator Characters, Status, Self Test, Memory Location (100 point memory), Dwell Time.

AS A CONSTANT VOLTAGE SOURCE

OUTPUT				COMPLIANCE (Source or Sink)		
RANGE	MAXIMUM	RESOLUTION	ACCURACY* (1 Year) 18°–28°C	MAXIMUM	RESOLUTION	ACCURACY (1 Year) 18°–28°C
100 V	±101.0 V	100 mV	±(0.1% + 0.1 V)	±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400µA)
10 V	±10.10 V	10 mV	±(0.1% + 10 mV)	±10.10 A	10 mA	±(0.5% + 40 mA)
				±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400µA)
1 V	±1.010 V	1 mV	±(0.1% + 1.0mV)	±10.10 A	10 mA	±(0.5% + 40 mA)
				±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400µA)

*Above 0.4% of range.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

NOISE:

RANGE	0.1–300 Hz	0.1–300 kHz	0.1–20 MHz*
100 V	2.5 mV p-p	15 mV p-p	25 mV p-p
10 V	1.0 mV p-p	15 mV p-p	25 mV p-p
1 V	0.35 mV p-p	15 mV p-p	25 mV p-p

*Typical.

OUTPUT RESISTANCE (maximum): 100V Range: 10mΩ. 10V Range: 100µΩ. 1V Range: 100µΩ.

OUTPUT INDUCTANCE: 100µH typical.

SENSING: REMOTE or LOCAL.

REMOTE SENSING: Corrects for up to 0.5V drop per output lead. Maximum 5Ω per sense lead for rated accuracy. Maximum 0.5Ω per sense lead for rated output resistance.

AS A CONSTANT CURRENT SOURCE

OUTPUT				COMPLIANCE (Source or Sink)		
RANGE	MAXIMUM	RESOLUTION	ACCURACY* (1 Year) 18°–28°C	MAXIMUM	RESOLUTION	ACCURACY (1 Year) 18°–28°C
10 A	±10.10 A	10 mA	±(0.5% + 10 mA)	±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)
1 A	±1.010 A	1 mA	±(0.1% + 1.0 mA)	±101.0 V	100 mV	±(0.1% + 400 mV)
				±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)
0.1 A	±0.1010 A	100 µA	±(0.1% + 0.1 mA)	±101.0 V	100 mV	±(0.1% + 400 mV)
				±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)

*Above 0.4% of range.

NOISE:

RANGE	0.1–300 Hz	0.1–300 kHz	0.1–20 MHz*
10 A	5 mA p-p	15 mA p-p	25 mA p-p
1 A	1.5 mA p-p	5 mA p-p	25 mA p-p
0.1 A	0.5 mA p-p	5 mA p-p	3 mA p-p

*Typical.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

OUTPUT RESISTANCE (min.): 10A Range: 10^4Ω. 1A Range: 10^5Ω. 0.1A Range: 10^6Ω.

OUTPUT CAPACITANCE: 0.2µF typical.

OUTPUT LOAD: Must be non-inductive.

GENERAL

DISPLAY: Dual 3½-digit LED (0.5 in.) displays indicate programmed values in Standby and output values in Operate.

FRONT PANEL PROGRAMS: COPY, SINK, IEEE Address, MOD V, MOD I, TEST, RESET.

READBACK ACCURACY: Same as output accuracy.

STANDBY: Programs output to 0V, 0A without changing ranges or polarity.

LOAD TRANSIENT RECOVERY TIME: With a resistive load the output will recover 90% of any load changes within 1ms after end of changes, provided the changes do not cause transfer to another control mode.

LINE REGULATION: <0.01% output change for AC power line changes within specified limits.

PROGRAM MEMORY (battery backed-up): Stores up to 100 output settings.
Range of Dwell Times: 10ms to 1000s.
Accuracy of Dwell Times: ±(0.05% + 2ms).

BATTERY BACKUP: Rechargeable 3.6V nickel-cadmium. 1 month retention of data with unit turned off.

TRIGGER: IN and OUT TTL-compatible.

PROGRAMMING RESPONSE TIME: <100ms on fixed range (typical).

MAXIMUM COMMON MODE VOLTAGE (output or output common to chassis): 100V DC.

OUTPUT CONNECTIONS: Quick disconnect card with screw terminals for output, modulation, current monitor, and external sense. BNC (chassis isolated) connectors for TRIGGER IN/OUT.

SELF TEST: Analog and digital circuits tested at power-on. Power supplies, temperatures, and output continuously monitored.

WARM-UP: 10 minutes to rated accuracy.

COOLING: Internal fan for forced air cooling.

POWER: 105–125 or 210–250V AC (internally switch selectable), 50 or 60Hz, 500VA maximum.

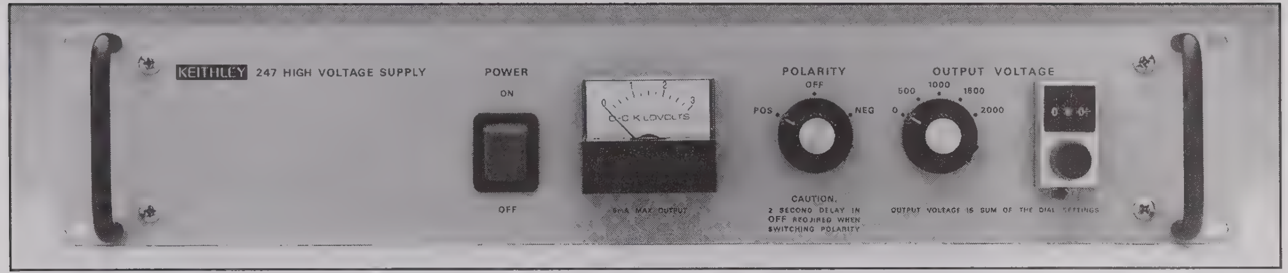
ENVIRONMENT: Operating: 0° to 50°C, <80% non-condensing RH below 35°C. **Storage:** –25° to 70°C.

DIMENSIONS, WEIGHT: 133mm high × 435mm wide × 448mm deep (5¼ in. × 17⅛ in. × 17⅝ in.). Net weight 10.9kg (24 lbs.).

ACCESSORIES SUPPLIED: Model 2286 Safety Output Connector, instruction manual.

High Voltage Power Supply

247


KEITHLEY 247 HIGH VOLTAGE SUPPLY
POWER
ON
OFF
KILOVOLTS
6mA MAX OUTPUT
POLARITY
OFF
POS
NEG
CAUTION.
2 SECOND DELAY IN OFF REQUIRED WHEN SWITCHING POLARITY
OUTPUT VOLTAGE
0
500
1000
1800
2000
OUTPUT VOLTAGE IS SUM OF THE DIAL SETTINGS

The Model 247 High Voltage Supply is a highly regulated 3000V DC, 6mA supply that complements the superior sensitivity characteristics of Keithley electrometers and picoammeters in applications such as photomultiplier tubes, resistivity testing, ion chambers, and radiation detectors.

Output Precision

The Model 247 has an output current of 6mA, sufficient to operate several devices at one time. The output stability of 0.01% per hour facilitates long term measurements. Any output voltage from 0 to 3000V may be set with 200mV resolution. The polarity reversal switch is particularly useful in resistivity testing.

Line Regulation

Sensitive measurements will not be disturbed by fluctuating line voltage, due to superior line regulation. A 10% line change causes less than 0.001% output change.

Low Noise

Low ripple and noise of 3mV p-p at 1kV, 1mA minimizes noise contribution to capacitive circuits such as ion chambers and resistivity cells.

Bench or Rack Mounting

The Model 247 is supplied with accessory mounting feet for bench applications. Rack mounting is accommodated by the 19-inch spaced holes in the front panel.

Solid State Design

Long life and low maintenance costs can be anticipated from the 247 due to its all solid state design. Output circuitry is protected against arcs and short circuits.

SPECIFICATIONS

OUTPUT:
Voltage: 0 to 3kV DC.
Current: 6mA DC maximum.
Polarity: Positive or negative with respect to chassis.

ACCURACY: ±(0.25% of setting + 1.5V DC) from 18° to 28°C.

RESOLUTION: Dial graduations of 200mV.

STABILITY: ±0.01% of setting/hr.; ±0.02% of setting/8 hrs., at constant temperature after ½-hour warm-up.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±50ppm/°C.

LINE REGULATION: 0.001% voltage change for 10% line variation.

LOAD REGULATION: 0.005% voltage change from no load to full load.

RIPPLE AND NOISE: 3.5mV rms, 10mV p-p @ 3kV, 6mA; 1mV rms, 3mV p-p @ 1kV, 1mA, 10Hz–100kHz.

SETTLING TIME: 4 seconds to within 1V with full resistive load.

OVERLOAD PROTECTION: Short circuit proof, arc protected, self restoring.

METER: Monitors voltage output.

ENVIRONMENT: Operating: 0° to 50°C, 0 to 80% relative humidity up to 35°C. **Storage:** –40° to 75°C.

CONNECTOR: Rear panel, MHV Type UG-931/U.

POWER: 90–125V/180–250V, 50–60Hz, 130VA.

DIMENSIONS, WEIGHT: 483mm wide x 89mm high x 273mm deep (19 in. × 3½ in. × 10¾ in.), excluding handles. Four holes spaced for rack mounting. Net weight 5.9kg (13 lbs.).

ACCESSORIES SUPPLIED: Instruction manual, UG-932/U mating connector, mounting feet for bench operation.

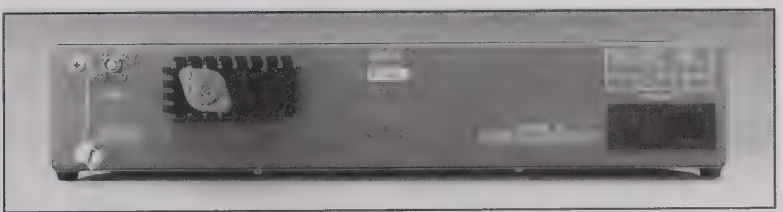
- **High stability**
- **Excellent line and load regulation**
- **Bench or rack mounting**

[illegible]

247
High Voltage Power Supply with Instruction Manual, UG-932/U mating connector, and mounting feet for bench operation.

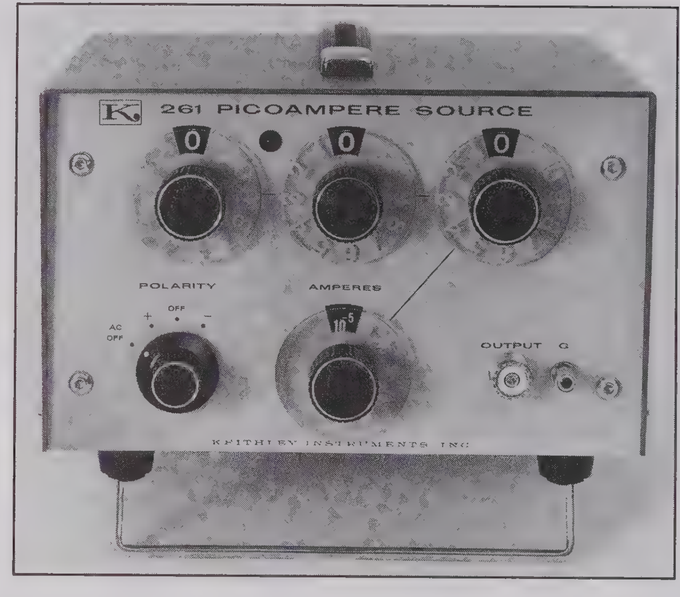
This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

See page 163 for descriptions of all accessories.



261 Picoampere Source

- **Output from 10^{-14}A to 1.1×10^{-4}A**
- **±0.25% accuracy at 10^{-7}A, ±0.7% at 10×10^{-12}A**
- **Secondary calibration standard**



ORDERING INFORMATION

261
Picoampere Source with Model 2611 Test Cable and Instruction Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

See page 163 for descriptions of all accessories.

The Model 261 Picoampere Source is a secondary standard for calibration of picoammeters and electrometers. It is a "passive" source, consisting of a selectable 0 to 10V voltage in series with a specially selected and tested hi-meg resistor.

Current output is 10^{-14}A to 1.1×10^{-4}A. Accuracy varies from ±(0.25% + 1 count) on 10^{-7} and higher ranges to ±(1.6% + 1 count) on the 10^{-11} range. Long term stability is better than ±0.15% per month (typically ±0.05% to ±0.1% per month) on the most sensitive ranges, beyond three months after calibration. Calibration maintains stated accuracy for three months.

The 261 may also be used as a decade resistance standard, having ±0.02% accuracy at $10^5\Omega$, ±0.1% accuracy at 10^6 and $10^7\Omega$, and ±0.5% accuracy at 10^8 through $10^{12}\Omega$.

The characterization of the hi-meg resistors is based on a 10-year Keithley program of collecting data on these components, and on individual time stability measurements of each resistor.

A calibration certificate including range resistor values, temperature coefficients, and temperature and date of calibration is furnished with each Model 261. Certification traceable to the National Institute of Standards and Technology and recalibration are also optionally available.

ACCURACY

RANGE SETTING	[illegible]	ACCURACY WITH 10.00 SETTING (10V SOURCE VOLTAGE)	WORST-CASE WITH SETTING OTHER THAN 10.00**
10^{-7} to 10^{-5}	10^{-7} to 1.1×10^{-4}	±0.25%	±0.25%
10^{-8}	10^{-8} to 10^{-7}	±0.5 %	±0.5 %
10^{-9}	10^{-9} to 10^{-8}	±0.6 %	±0.8 %
10^{-10}	10^{-10} to 10^{-9}	±0.6 %	±1.1 %
10^{-11}	10^{-11} to 10^{-10}	±0.6 %	±1.3 %
10^{-12}	10^{-12} to 10^{-11}	±0.7 %	±1.6 %
10^{-12}	10^{-14} to 10^{-12}	—	±2.0 %

*Exclusive of input drop consideration:

**All accuracies are ± the percentage given, ±0.01 × range switch setting.

OUTPUT: 10^{-14}A (10^{-11}A full range) to 1.1×10^{-4}A, positive or negative, in eight decade ranges.

LONG-TERM STABILITY: Will operate within stated specifications for three months after calibration. After three months add 0.15% per month to 10^{-8} through 10^{-12}A range setting accuracy specifications.

TEMPERATURE COEFFICIENT: ±0.1%/°C from 15°C to 30°C on 10^{-7} to 10^{-5}A range settings. Approximately 0.15%/°C on 10^{-12} to 10^{-8}A range settings. Exact values for these ranges supplied with instrument.

WARM-UP TIME: 1 hour.

LINE REGULATION: 0.01% for 10% change in line voltage.

SOURCE VOLTAGE: 0 to 11V in 0.01V steps.

RESOLUTION: 3 significant figures from 10^{-12}A to 1.1×10^{-4}A.

RANGE RESISTORS: 10^5 to $10^{12}\Omega$ in decade steps; ±5%.

RANGE RESISTOR ACCURACY: Value with power on, given on certificate.

±0.5 %:	10^8 to $10^{12}\Omega$
±0.1 %:	10^7 to 10^6 Ω
±0.02%:	$10^5\Omega$.

OUTPUT ISOLATION: Low to ground: $>10^9\Omega$ shunted by 0.001µF.

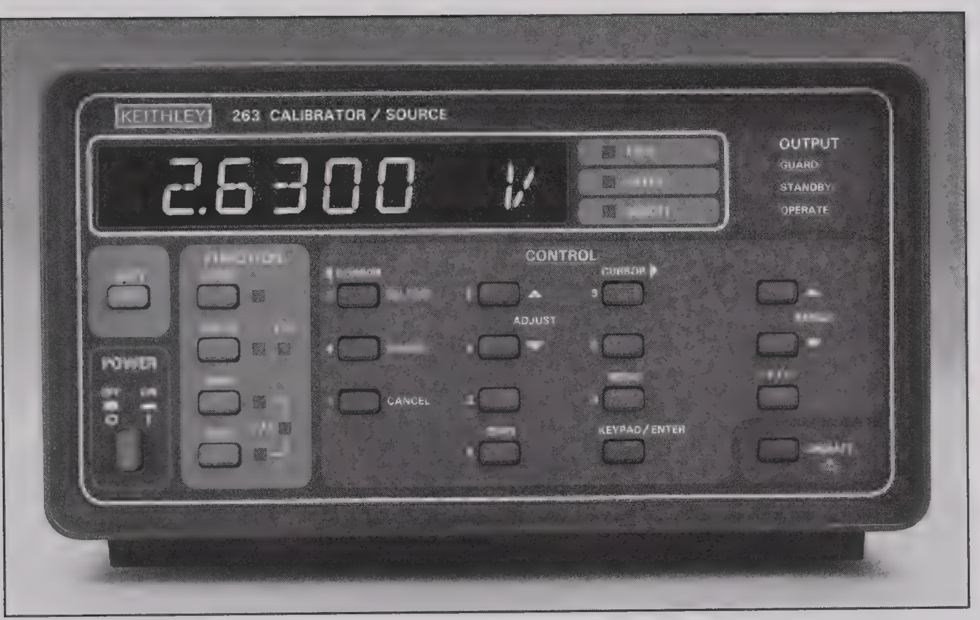
CERTIFICATION: A Calibration Certificate is furnished including range resistor values, thermal coefficients, temperature and date of calibration. Certification traceable to the National Institute of Standards and Technology is also available.

POWER: 105–125V or 210–250V (switch selected), 50–60Hz, 6W.

DIMENSIONS, WEIGHT: 155mm high × 225mm wide × 300mm deep (6¼ in. × 9 in. × 12 in.). Net weight 4.1kg (9 lbs.).

ACCESSORY SUPPLIED: Model 2611 Test Cable, instruction manual.

Calibrator/Source 263



The Model 263 Calibrator/Source is a secondary standard for use when calibrating electrometers and picoammeters (or wherever a precision low current, high resistance, voltage, or charge is needed). Designed for use as a multifunction calibrator/source, the 263 can source current, resistance, voltage, and charge. A built-in voltage source provides 5μV to 20V. Where more than 20V is required, the Model 263 can switch up to 200V from an external voltage source to its output terminals.

Source Current/Charge Actively or Passively

The Model 263 is capable of sourcing current or charge either actively or passively. If the voltage burden is small or known, the 263 can be operated as a passive source (V/R mode), whereby offset errors associated with the lower current ranges will be reduced. If the voltage burden is large or unknown, the 263 can be operated as an active current source; its current output will be constant, but larger offset errors will result on the lower current ranges.

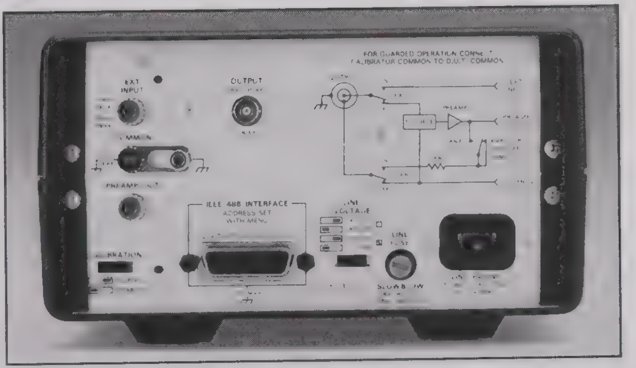
Precision Resistance Standards

The 263 includes 9 precision resistors from $10^3\Omega$ to $10^{11}\Omega$ in decade steps The actual calibration value of these high stability resistors is displayed as each range is selected. When generating low currents or displaying high megohm resistance values, the Model 263 uses an internal temperature measuring circuit to adjust low currents and high resistance values for any changes in ambient temperature. This results in accurate, reliable readings you can trust, free from the error associated with large temperature coefficients.

Easy and Convenient to Use

The Model 263 has been designed for easy pushbutton operation. All functions, ranges, and settings can be entered from the front panel. In addition, for automated applications, the 263 comes with an IEEE-488 bus interface. All front panel features are programmable.

A calibration certificate including temperature and date of calibration is furnished with each Model 263. Certification traceable to the National Institute of Standards Technology and recalibration are also optionally available.


FOR GUARDED OPERATION CONNECT CALIBRATOR COMMON TO D.U.T. COMMON
EXT INPUT
OUTPUT
COMMON
PREAMP OUT
IEEE 488 INTERFACE ADDRESS SET WITH MENU
LINE VOLTAGE
LINE FUSE
SLOW BLOW
CALIBRATION

- 10^{-14}A to 2×10^{-2}A
- IEEE-488 interface
- Easy to use and maintain
- Secondary calibration standard

IEEE-488

ORDERING INFORMATION

263
Calibrator/Source with IEEE-488 Interface, 7024-3 Low Noise Triax Cable, Instruction Manual

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

ACCESSORIES AVAILABLE

TEST LEADS

6011	Input Leads, 2-Slot Male Triax to Alligator Clips, 1.5m (5 ft.)
6011-10	Input Leads, 2-Slot Male Triax to Alligator Clips, 3m (10 ft.)

ADAPTERS

6146	Triax Tee Adapter
6147	2-Slot Male Triax to Female BNC Adapter
6172	2-Slot Male to 3-Lug Female Triax Adapter

CABLES

7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)
7007-2	Shielded IEEE-488 Cable, 2m (6.4 ft.)
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)
7024-3	Low Noise Triax Cable, 0.9m (3 ft.)
7024-10	Low Noise Triax Cable, 3m (10 ft.)

RACK MOUNT KITS

1019A-1	Single Fixed Rack Kit
1019S-1	Single Slide Rack Kit
1019A-2	Dual Fixed Rack Kit
1019S-2	Dual Slide Rack Kit

See page 163 for descriptions of all accessories.

263 Calibrator/Source

AMPS V/R (Passive)

RANGE	STEP SIZE	ACCURACY ±(% setting + offset) 18°–28°C 90 Days	1 Year	TEMPERATURE COEFFICIENT ±(% setting + offset)/°C 0°–18°C & 28°–50°C	OUTPUT RESISTANCE
2 pA	50 aA	0.375 + 10 fA	0.425 + 10 fA	0.04 + 2 fA	100 GΩ
20 pA	500 aA	0.325 + 10 fA	0.375 + 10 fA	0.04 + 2 fA	100 GΩ
200 pA	5 fA	0.20 + 30 fA	0.25 + 30 fA	0.01 + 2 fA	10 GΩ
2 nA	50 fA	0.0625 + 100 fA	0.065 + 100 fA	0.01 + 30 fA	1 GΩ
20 nA	500 fA	0.0625 + 1 pA	0.065 + 1 pA	0.0035 + 100 fA	100 MΩ
200 nA	5 pA	0.035 + 10 pA	0.035 + 10 pA	0.0025 + 1 pA	10 MΩ
2 µA	50 pA	0.025 + 100 pA	0.025 + 100 pA	0.0025 + 10 pA	1 MΩ
20 µA	500 pA	0.025 + 1 nA	0.025 + 1 nA	0.0025 + 100 pA	100 kΩ
200 µA	5 nA	0.025 + 10 nA	0.025 + 10 nA	0.0025 + 1 nA	10 kΩ
2 mA	50 nA	0.025 + 100 nA	0.025 + 100 nA	0.0025 + 10 nA	10 kΩ
20 mA	500 nA	0.15 + 1 µA	0.15 + 1 µA	0.0025 + 100 nA	1 kΩ

[1] Assumes <100µV compliance (voltage burden).

COULOMBS V/R (Passive)

RANGE	STEP SIZE	ACCURACY ±(% setting + offset) 1 Year	TEMPERATURE COEFFICIENT ±(% setting + offset)/°C 0°–18°C & 28°–50°C	OUTPUT RESISTANCE
20 pC	0.5 fC	1.0 + 50 fC	0.05 + 10 fC	100 GΩ
200 pC	5 fC	0.5 + 75 fC	0.01 + 10 fC	10 GΩ
2 nC	50 fC	0.1 + 300 fC	0.01 + 10 fC	1 GΩ
20 nC	500 fC	0.1 + 3 pC	0.01 + 100 fC	100 MΩ
200 nC	5 pC	0.5 + 30 pC	0.01 + 1 pC	10 MΩ
2 µC	50 pC	0.5 + 300 pC	0.01 + 10 pC	1 MΩ
20 µC	500 pC	0.5 + 3 nC	0.01 + 100 pC	100 kΩ

[1] Measurement interval is 2.5 seconds. Assumes <100µV of compliance (voltage burden).

COULOMBS (Active)

Accuracy is the same as COULOMBS V/R except change the offset to 300fC on the 20pC and 200pC ranges.

VOLTS

RANGE	STEP SIZE	ACCURACY ±(% setting + offset) 18°–28°C 90 Days	1 Year	TEMPERATURE COEFFICIENT ±(% setting + offset)/°C 0°–18°C & 28°–50°C
200 mV	5 µV	0.0125 + 15 µV	0.0175 + 15 µV	0.002 + 0.5 µV
2 V	50 µV	0.0125 + 50 µV	0.0175 + 50 µV	0.002 + 2 µV
20 V	500 µV	0.0125 + 500 µV	0.0175 + 500 µV	0.002 + 20 µV

[1] Load resistance >100kΩ.

RESPONSE TIME: <0.5 second to rated accuracy.

OUTPUT RESISTANCE: <1Ω.

SHORT CIRCUIT CURRENT LIMIT: <75mA.

NOISE: <25ppm of range peak to peak in a 0.1Hz to 10Hz bandwidth.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, UNL, UNT, GTL.

UNILINE COMMANDS: REN, ATN, EOI, IFC, SRQ.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT0, C0, E1.

PROGRAMMABLE PARAMETERS: Function, Range, Value, Zero, Operate, Guard, Digital Calibration, Temperature Compensation, Terminator, Status, Data Format, SRQ.

AMPS (Active)

Accuracy is the same as V/R, except change % setting on the 20mA range to 0.035% and change the offsets per the following table:

RANGE	ACCURACY ± offset	TEMPERATURE COEFFICIENT ± offset/°C
2 pA	100 fA	30 fA
20 pA	100 fA	30 fA
200 pA	120 fA	30 fA
2 nA	200 fA	No change

OUTPUT RESISTANCE: >10^{14}Ω.

OUTPUT CAPACITANCE: <50pF.

OUTPUT LOAD: Output load must be non-inductive.

COMPLIANCE VOLTAGE: >12V. Front panel OPERATE light flashes when compliance is reached.

MAXIMUM OPEN CIRCUIT VOLTAGE: <45V for the 2mA and 20mA ranges; <25V for the 2pA–200µA ranges.

RESPONSE TIME: <0.5 second to rated accuracy for the 2nA–20mA ranges; <5 seconds for the 2pA–200pA ranges.

PREAMP OUTPUT: Maximum Load Current: 5mA.
Maximum Load Capacitance: 10nF.

OHMS

NOMINAL VALUE	ACCURACY ±(% setting) 18°–28°C 90 Days	1 Year	TEMPERATURE COEFFICIENT ±(% setting/°C) 0°–18°C & 28°–50°C
1 kΩ	0.04[1]	0.04[1]	0.0005
10 kΩ	0.02[1]	0.02[1]	0.0005
100 kΩ	0.02	0.02	0.0005
1 MΩ	0.025	0.025	0.0005
10 MΩ	0.035	0.0375	0.0015
100 MΩ	0.065	0.07	0.0015
1 GΩ	0.08	0.10	0.008[2]
10 GΩ	0.20	0.225	0.008[2]
100 GΩ	0.375	0.40	0.04[2]

[1] After subtracting ZERO offset.

[2] Displayed value corrected for resistor temperature coefficient.

ZERO OFFSET: <1Ω.

TOLERANCE OF NOMINAL VALUE: 1kΩ–1MΩ, 0.1%; 10MΩ, 0.2%; 100MΩ–100GΩ, 3%.

MAXIMUM VOLTAGE ACROSS RESISTANCE FOR RATED ACCURACY: 1kΩ–10GΩ, 20V; 100GΩ, 100V.

GENERAL

DISPLAY: 5½-digit numeric LEDs with appropriate decimal point and polarity indication; signed two-digit alphanumeric exponent.

OUTPUT CONNECTIONS: Two-lug triaxial connector for output; five-way binding posts for PREAMP OUT, COMMON, and EXT INPUT. All connections on rear panel.

PROGRAMS: Menu provides front panel access to IEEE-488 address, Alpha or Numeric Exponent, Digital Calibration, and Temperature Compensation selection.

MAX. COMMON MODE VOLTAGE (DC to 60Hz sinewave): 350V peak.

ISOLATION (Common to Chassis): >10^{10}Ω paralleled by <500pF.

EXT INPUT: Max. Input: 200V peak, 100mA peak. **Series Resistance:** <1Ω.

WARM-UP: 1 hour to rated accuracy.

ENVIRONMENT: Operating: 0°–50°C; <70% RH non-condensing up to 35°C. **Storage:** –25° to +60°C.

POWER: 105–125V or 210–250V (rear panel switch selected), 90–110V available, 50–60Hz, 25VA maximum.

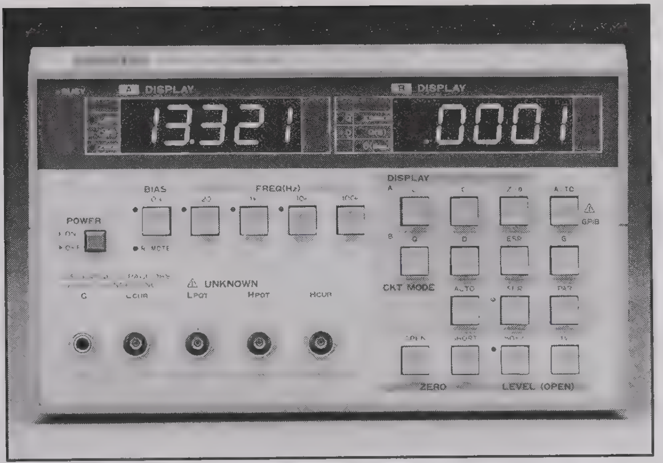
DIMENSIONS, WEIGHT: 127mm high × 216mm wide ×359mm deep (5 in. × 8½ in. × 14⅛ in.) . Net weight 3.6kg (8.1 lbs).

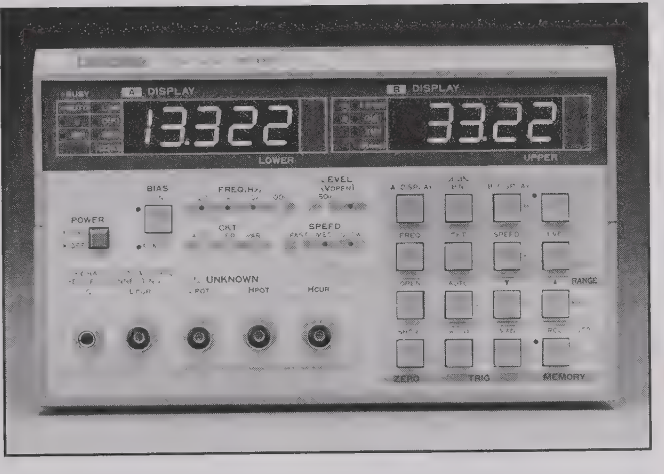
ACCESSORY SUPPLIED: Model 7024-3 Triax Cable, instruction manual.

LCZ Meters

3321, 3322

These instruments are for precision component or circuit testing in R&D labs, component test labs, inspection, qualification and reliability labs, and on the production line. Both are very easy to use, cost effective, and provide accurate measurements of L, C, or |Z| and θ, along with D, Q, G, or ESR. The Model 3322 also directly reads R and X, and has a % deviation and binning function.





High Precision

Both models have 4½-digit resolution, and 0.1% basic accuracy. D and Q resolution is 0.0001, and θ resolution is 0.01°. These instruments provide top-of-the-line lab accuracy combined with low cost and easy operation.

Automatic Settings

Both instruments have automatic selection of function and equivalent circuits. In the AUTO mode, no knowledge of any controls is required; operation is literally as simple as connecting the DUT and reading the L,C, or |Z| and θ of the DUT. Anytime additional information is desired, easily understood front panel controls may be used. Additionally, the Model 3322 has battery-backed-up memory to store ten front panel control settings.

Selectable Test Frequency and Voltage

The Model 3322 has 11 test frequencies up to 100kHz. The Model 3321 has test frequencies of 120Hz, 1kHz, 10kHz and 100kHz. Both units have selectable 1V or 50mV AC test voltages, permitting components to be tested at small signal levels or with minimum noise.

Built-In DC Bias

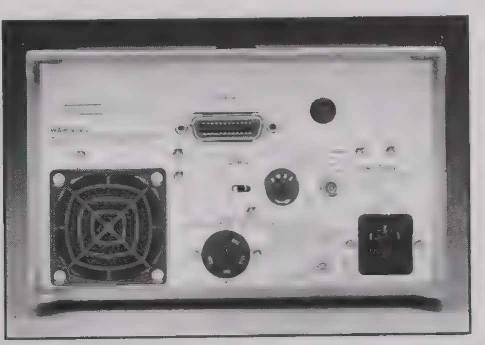
A 2V bias source is built in for electrolytic capacitor and semiconductor test. Externally supplied voltages up to 35V may also be used.

% Deviation and Binning

The Model 3322 also has capability to read % deviation from a preset value, and identify which of up to 20 preset "bins" the measured value of a DUT falls into.

Measurement Speed

The Model 3322 has selection of FAST (to 64ms per measurement), MED or SLOW reading rates. Manual trigger, with a delay time of 0 to 199.9s, may also be used. The Model 3321 automatically selects MED (150ms) or SLOW rates. Both have built-in IEEE-488 interfaces for computer control and data collection.



Two new cost-effective LCZ meters: both easy to use, 4½ digits, DC bias capability, and built-in IEEE-488 interface.

MODEL 3321:

- 0.1% accuracy.
- Low cost.
- Automatic function and circuit selection: just connect the DUT and read.
- Four test frequencies to 100kHz.

MODEL 3322:

- 0.1% accuracy.
- Low cost.
- Automatic function and equivalent circuit selection.
- Binning and deviation capability.
- Eleven frequencies in 1, 2, 5 steps to 100kHz.
- Front panel setup memory.

IEEE-488

[illegible]

3321
LCZ Meter with operating manual, power cable and fuses

3322
LCZ Meter with operating manual, power cable and fuses

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

[illegible]

TEST FIXTURE	
3323	Test Fixture
TEST LEADS	
3324	4-Terminal Alligator Clip Test Leads
3325	Kelvin Clip Test Leads
3326	Chip Component Test Leads
CABLES	
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5:	BNC Interconnect Cable, 1.5m (5 ft.)
RACK MOUNT KITS	
3900-1	Single Fixed Rack Mount Kit
3900-2	Dual Fixed Rack Mount Kit

See page 163 for descriptions of all accessories.

3321,3322 LCZ Meters

ACCURACY OF IMPEDANCE (|Z|) AND ANGLE (θ)

FOR 0.2Ω ≤ |Z| ≤ 20 MΩ:

[illegible]

3321 Frequency, [Hz]	120		1k		10k			100k
3322 Frequency, [Hz]	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
10M ≤ |Z| < 20M	3.0% 1.5°	2.0 % 1.0°	1.0% 0.8°	2.0% 1.5°	3.5% 2.0°	4.0% 3.0°	14.0% 8.0°	20.0% 12.0°
5M ≤ |Z| < 10M	1.5% 0.9°	1.0% 0.6°	0.5% 0.4°	1.0% 0.6°	1.8% 1.1°	2.0% 1.3°	7.0% 4.0°	10.0% 6.0°
2M ≤ |Z| < 5M	0.75% 0.45°	0.5% 0.3°	0.3% 0.2°	0.5% 0.3°	0.9% 0.6°	1.0% 0.6°	3.5% 2.0°	5.0% 3.0°
1M ≤ |Z| < 2M	0.36% 0.22°	0.3% 0.15°	0.2% 0.1°	0.3% 0.15°	0.4% 0.2°	0.5% 0.3°	1.6% 1.0°	3.0% 2.0°
200k ≤ |Z| < 1M	0.25% 0.15°	0.2% 0.12°	0.15% 0.09°	0.2% 0.12°	0.27% 0.16°	0.35% 0.2°	1.0% 0.6°	2.0% 1.2°
20k ≤ |Z| < 200k	0.15% 0.10°	0.12% 0.06°	0.1% 0.04°	0.18% 0.08°	0.25% 0.15°	0.3% 0.2°	0.6% 0.4°	1.2% 0.8°
2k ≤ |Z| < 20k	0.14% 0.09°	0.12% 0.05°	0.1% 0.03°	0.12% 0.06°	0.15% 0.08°	0.2% 0.12°	0.4% 0.3°	0.8% 0.6°
10 ≤ |Z| < 2k	0.13% 0.08°	0.11% 0.05°	0.1% 0.03°	0.11% 0.08°	0.13% 0.1°	0.17% 0.15°	0.4% 0.25°	0.7% 0.5°
2 ≤ |Z| < 10	0.25% 0.15°	0.2% 0.1°	0.15% 0.07°	0.2% 0.12°	0.32% 0.2°	0.5% 0.3°	0.8% 0.4°	1.5% 0.8°
1 ≤ |Z| < 2	0.35% 0.22°	0.3% 0.2°	0.2% 0.12°	0.25% 0.15°	0.5% 0.3°	0.7% 0.4°	1.0% 0.6°	2.0% 1.2°
0.5 ≤ |Z| < 1	0.7% 0.45°	0.6% 0.4°	0.4% 0.25°	0.5% 0.3°	0.8% 0.5°	1.2% 0.7°	1.7% 1.0°	3.3% 2.0°
0.2 ≤ |Z| < 0.5	1.4% 0.9°	1.1% 0.7°	0.8% 0.5°	1.1% 0.7°	1.25% 0.8°	1.8% 1.1°	2.7% 1.6°	5.5% 3.0°

TABLE 2: |Z|, Ω LEVEL = 50mV rms, SPEED = MED or SLOW for 3322

3321 Frequency, [Hz]	120		1k		10k			100k
3322 Frequency, [Hz]	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
10M ≤ |Z| < 20M	7.0% 4.0°	4.5% 2.5°	3.5% 2.0°	6.0% 3.5°	8.5% 5.0°	17.0% 10.0°		
5M ≤ |Z| < 10M	3.5% 2.0°	2.2% 1.3°	1.7% 1.0°	2.7% 1.6°	3.5% 2.0°	7.0% 4.0°		
2M ≤ |Z| < 5M	2.0% 1.2°	1.2% 0.8°	0.9% 0.6°	1.2% 0.8°	1.6% 1.0°	3.5% 2.0°		
1M ≤ |Z| < 2M	1.0% 0.6°	0.6% 0.35°	0.4% 0.25°	0.6% 0.35°	0.8% 0.5°	1.6% 0.9°	12.0% 7.0°	14.0% 8.0°
200k ≤ |Z| < 1M	0.5% 0.3°	0.4% 0.25°	0.3% 0.18°	0.35% 0.20°	0.4% 0.25°	0.7% 0.4°	6.0% 3.6°	7.0% 4.0°
20k ≤ |Z| < 200k	0.3% 0.18°	0.2% 0.12°	0.16% 0.08°	0.24% 0.14°	0.32% 0.18°	0.40% 0.23°	1.8% 1.0°	3.0% 1.5°
2k ≤ |Z| < 20k	0.25% 0.15°	0.18% 0.09°	0.16% 0.06°	0.2% 0.12°	0.24% 0.14°	0.35% 0.20°	1.4% 0.8°	2.0% 1.2°
10 ≤ |Z| < 2k	0.20% 0.12°	0.18% 0.09°	0.15% 0.06°	0.20% 0.12°	0.23% 0.13°	0.32% 0.18°	1.2% 0.7°	1.6% 1.0°
2 ≤ |Z| < 10	0.5% 0.3°	0.35% 0.20°	0.25% 0.14°	0.35% 0.20°	0.5% 0.3°	0.7% 0.4°	3.4% 2.0°	4.0% 2.3°
1 ≤ |Z| < 2	1.0% 0.6°	0.6% 0.4°	0.5% 0.3°	0.6% 0.4°	0.8% 0.5°	1.1% 0.7°	6.0% 3.6°	8.0% 5.0°
0.5 ≤ |Z| < 1	1.8% 1.1°	1.2% 0.7°	1.0% 0.6°	1.2% 0.7°	1.5% 0.9°	1.8% 1.1°	10.0% 6.0°	14.0% 8.5°
0.2 ≤ |Z| < 0.5	3.7% 2.2°	2.6% 1.5°	2.0% 1.2°	2.6% 1.5°	2.9% 1.7°	3.4% 2.0°	21.5% 13.0°	28.0% 16.0°

|Z| Accuracy: ± % or reading shown on upper line.
θ Accuracy: ± degrees shown on bottom line.
When 3322 speed = fast, accuracy is 2 times amount shown.

FOR |Z| > 20 MΩ, OR |Z| < 0.2Ω:

[illegible]

3321 Frequency, [Hz]	120		1k		10k			100k
3322 Frequency, [Hz]	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0 ≤ |Y| ≤ 50nS	1.8nS	1.2nS	0.6nS	1.2nS	2.1nS	2.4nS	7.5nS	12nS
0 ≤ |Z| < 0.2	1.7% +0.2m	1.5% +0.2m	1.0% +0.2m	1.3% +0.2m	1.4% +0.3m	2.0% +0.6m	3.0% +1.5m	6.0% +3m

FOR |Z| > 20 MΩ:
|Z| Accuracy: Specified by the ± deviation (S) of admittance shown in Table 3.
θ Accuracy: (θ Accuracy for 10MΩ ≤ |Z| < 20M in Table 1) × (|Z|/20MΩ).
FOR |Z| < 0.2 Ω:
|Z| Accuracy: ± (% reading + R) shown in Table 3.
θ Accuracy: (θ Accuracy for 0.2Ω ≤ |Z| < 0.5 in Table 1) × F (0.2Ω/|Z|).
When 3322 speed = FAST, accuracy is 2 times amount shown.

WARM-UP TIME: 30 minutes.

TEMPERATURE: 23°C ± 5°C.

HUMIDITY: ≤ 90% RH.

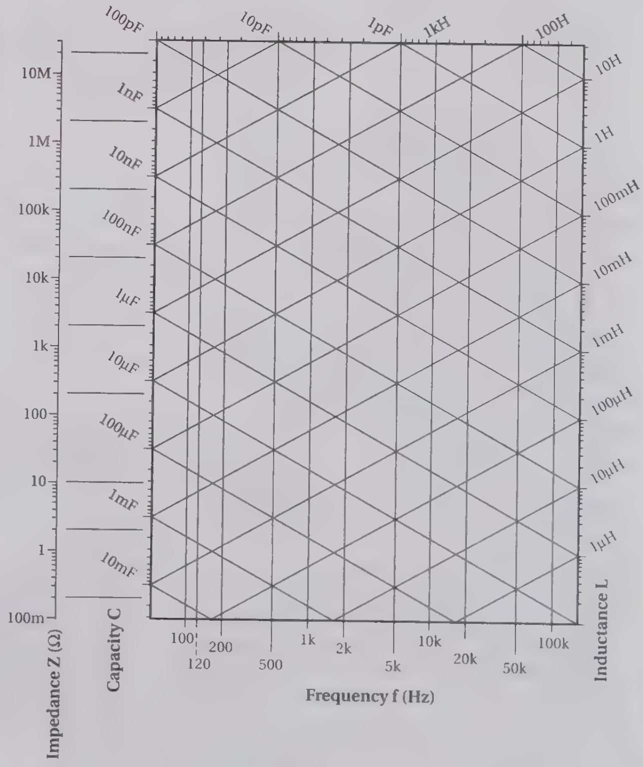
ZERO CORRECTION: Performed under above conditions.

CALIBRATION PERIOD: 12 months.

NOTES:

1. When measurement is made at twice line frequency, the measured value may deviate beyond the accuracy range due to interaction with line frequency.
2. Formulas for accuracy at any specific impedance level are given in the Instruction Manual. Tables 1, 2, and 3 indicate the worst accuracy in the stated impedance range.

CONVERSION DIAGRAM FROM LC TO |Z|



ACCURACY (continued)

ACCURACY OF R, ESR AND G:
In the case of Q < 0.1 (D>10), use the accuracy of |Z|:
$|R| = |Z|$, $|ESR| = |Z|$, $|G| = 1/|Z|$.

ACCURACY OF L, C AND X:
In the case of Q >10 (D < 0.1) use the accuracy of |Z|:

$$L = \frac{|Z|}{2\pi f}, \quad C = \frac{1}{2\pi f\,|Z|}, \quad |X| = |Z|,$$

where f is the test frequency in Hz.
Refer to the conversion diagram from LC to |Z|.

ACCURACY OF D AND Q
In the case of D << 1 (Q >> 1), use the following equations:
Accuracy of D = ±(0.0175 × θ accuracy (deg))
Accuracy of Q = ±(0.0175 × θ accuracy (deg) × Q^2)

MEASURING PARAMETERS

MAIN PARAMETERS:

AUTO	Selects the main parameters, sub-parameters and equivalent circuits automatically.
L	Self-inductance (unit: H, Henry)
C	Electrostatic capacity (unit: F, Farad)
R	Resistance (unit: Ω, Ohm), Model 3322 only
|Z|	Magnitude of impedance (unit: Ω, Ohm)

There are series and parallel measuring modes for each of L, C and R.

SUB-PARAMETERS:

Q	Quality factor (quality of circuit)
D	Dissipation factor (= tan δ = 1/Q)
ESR	Equivalent series resistance (unit: Ω)
G	Parallel conductance (unit: S, Siemens)
X	Series reactance (unit: Ω), Model 3322 only
θ	Phase angle of impedance (unit: degree)

DEVIATION DISPLAY (Model 3322): Deviation and deviation of main parameter (not available for sub-parameter). Possible measurement range of deviation is ±100% or more for Δ and ±199.99% for Δ%.

NUMBER OF BINS (Model 3322): 20 max.

MEASURING (DISPLAY) RANGE:

R, |Z|, ESR, X:	0.1 mΩ	to	19.999 MΩ
C:	0.001 pF	to	199.99 mF
L:	0.1 nH	to	19.999 kH
Q, D:	0.0001	to	19999
G:	0.001 µS	to	199.99 S
θ:	–180.00 °	to	+179.99 °

These ranges are dependent on the frequency, measuring range and phase angle of impedance.

MEASURING SIGNAL

FREQUENCY:
Model 3322: 100, 120, 200, 500, 1k, 2k, 5k, 10k, 20k, 50k, or 100k [Hz].
Model 3321: 120, 1k, 10k or 100k [Hz].
Accuracy: ±50 ppm (±0.005%).

SIGNAL LEVEL (Voltage with drive terminal H CUR open):

1V rms:	±3% at 1kHz, ± 4% at 100Hz to 20kHz ±5% at 50kHz and 100kHz
50mV rms:	±5% at 1kHz, ± 6% at 100Hz to 20kHz ±7% at 50kHz and 100kHz

DC BIAS:
Internal: 2V, ± 5%.
External: 0 to 35V.

MEASURING RANGE

NUMBER OF RANGES: 6.

SELECTION: **Model 3322:** Automatic or manual.
Model 3321: Automatic.

MEASURING TIME (reference value, fixed range and auto trigger mode):

	Typical at 1kHz, 1kΩ	Maximum on any range, any frequency
FAST:	64 ms	80 ms
MED:	150 ms	245 ms
SLOW:	480 ms	600 ms

Model 3322: Selectable among above three measuring times.

Model 3321: Automatic switching (equivalent to MED or SLOW).

TRIGGER

TRIGGER MODES:
Model 3322: Automatic (repeat) and manual.
Model 3321: Automatic only.

TRIGGER DELAY TIME: 0 to 199.99s.

MEASUREMENT TERMINALS

4 terminals (BNC-R) + guard terminal.

FRONT PANEL SETUP MEMORY (Model 3322)

NUMBER OF SETUPS: 10.

CONTENT OF MEMORY: All setting data other than bias on-off.

LIFE OF BATTERY: 3 years or longer after delivery.

GPIB

SETTING: Of the items settable via the front panel, all the parameters except address and delimitter of GPIB can be set. Also trigger, OPEN/SHORT compensation and memory operation can be performed.

READOUT: All the settable parameters, measurement data and status.

STANDARDS: Based on IEEE-488-1978 and IEEE-488A-1980.

CODE: ISO 7 bit code (ASCII code).

GENERAL

POWER REQUIREMENTS: AC line voltage: selectable to 100V, 120V, 220V, 240V ±10% (250V max.). 48 to 62Hz, approx. 21VA.

OPERATING ENVIRONMENT: 0° to 40°C, 10 to 90% RH (non-condensing).

STORAGE ENVIRONMENT: –10 to +50°C, 10 to 80% RH (non-condensing).

DIMENSIONS, WEIGHT: 216mm wide × 132.5mm high × 350mm deep (8½ in. × 5¼ in. × 13¾ in.), excluding protrusions. Net weight 3.6kg (7.9 lb.).

ACCESSORIES SUPPLIED: Operating manual, power cable, fuse (0.5A, 250V, normal acting type ϕ5.2×20mm), fuse (0.1A, 250V, quick acting type ϕ5.2×20mm).

Multifunction Synthesizers

Model 3940

- **0 - 20MHz with 0.1mHz resolution**
- **5ppm accuracy**
- **Arbitrary waveforms**
- **12 digit resolution**
- **Main synthesizer plus sub-synthesizer**
- **Accurate voltage output over frequency range**
- **Phase continuous**

Model 3930A

- **0 - 1.2MHz with 0.1mHz resolution**
- **5ppm accuracy**
- **11 digit resolution**
- **Accurate voltage output over frequency range**
- **30V p-p output voltage**
- **Phase continuous**
- **Used with Model 3933A for phase shifting**

Model 3910

- **0 - 1.0MHz with 0.1mHz resolution**
- **30ppm accuracy**
- **11 digit resolution**
- **Accurate voltage output over frequency range**
- **20V p-p output voltage**

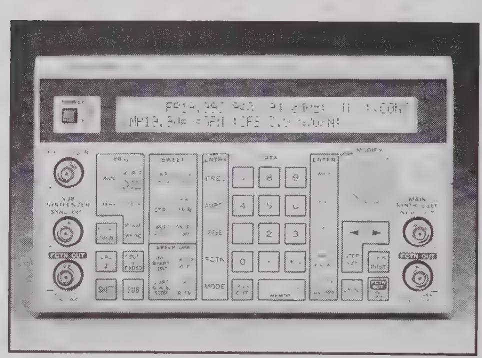
[illegible]

3910
Function Synthesizer with Instruction Manual

3930A
Multifunction Synthesizer with Instruction Manual

3940
Multifunction Synthesizer with Instruction Manual

This product is available with an Extended Warranty. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**



Model 3940

Synthesizer Overview

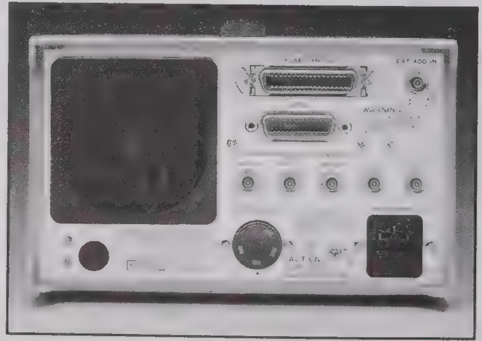
Keithley's three new Multifunction Synthesizers achieve the highest level of precision in phase continuity and frequency by using Direct Digital Synthesis. In addition, very accurate voltage amplitude is maintained over the entire frequency range.

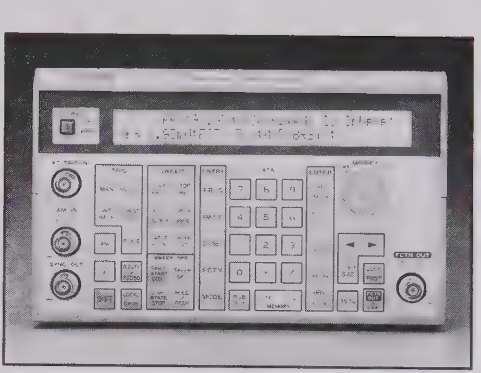
The Model 3900 Series offers a wide range of functions, which makes them useful in applications ranging from R&D to the production line. Features include a wide variety of built-in waveforms (∿ , ⋀⋁ , ⊓_ , ⊓_ (variable duty ratio), ⟋| , and ⟍|) and arbitrary waveforms (Model 3940 only). Additional functions include trigger/burst/gate functions, a variety of sweep functions, and synchronous-operation capability, on/off oscillation control, and convenient front panel operation. To enable automated measurements, GPIB is standard on the 3930A, 3933A, and 3940, and optional on the Model 3910.

These Multifunction Synthesizers provide accurate results in a wide variety of applications, including:

- vibration analysis
- automotive electronics
- general purpose circuit test
- servo-motor testing
- sensor analysis
- magnetic material analysis
- medical
- actuator drive waveforms
- radar and sonar.

Model 3940





Model 3930A

Direct Digital Synthesis Advantages

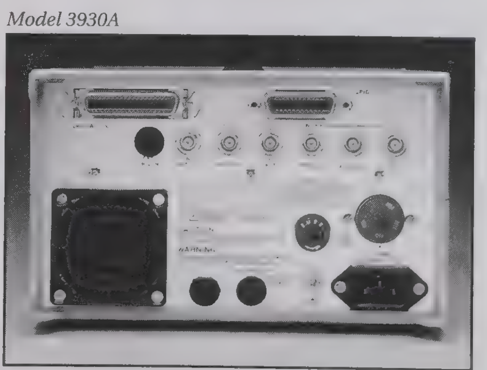
Direct Digital Synthesis is a breakthrough in development over older techniques used in standard function generators and PLL synthesizers. Function generators typically have frequency accuracy of 2–5% compared to the accuracy of Direct Digital Synthesis at 0.0005%. In addition, function generators are not phase continuous and their waveforms are not as precise at low frequencies.

PLL Synthesizers typically have good frequency accuracy, but cannot change frequency quickly. This disadvantage becomes apparent when changing frequency during a sweep, or stepping from one frequency to another. PLL Synthesizers take several cycles to stabilize to the new frequency, while Direct Digital Synthesizers change immediately with no dead time. Phase continuity is usually lost while the PLL is finding the new frequency.

Model 3930A and 3940

The 3930A and 3940 are full featured oscillators that offer the inherent advantages of Direct Digital Synthesis. Both have 0.1mHz resolution and ±5ppm accuracy, with a frequency range of 1.2MHz (3930A) or 20MHz (3940). Settings in terms of period are provided as a convenience for pulse applications. The maximum output of 30V p-p (3930A) and 20V p-p (3940) can be set as peak-to-peak, rms or dBV with high accuracy. Parameters are set by numeric keys or the Modify dial. The Modify step can be set to +1 or ×2 (÷2) or ×10 (÷10).

Model 3930A



Multifunction Synthesizers

Arbitrary waveforms captured with a digital storage oscilloscope or data recorder can be easily downloaded to the Model 3940 via computer. These waveforms are stored as data values in 1024 RAM locations. The maximum repetition rate is 1MHz.

Sweep

The Model 3930A and 3940 can also be used as high-performance sweep generators. The type of sweep can be selected as linear, logarithmic, or stepped, with increasing or decreasing frequency, single-direction or reciprocating , and single or repeated sweep. Excellent repeatability is achieved due to Direct Digital Synthesis. The rear panel features X-drive, marker, and sweep-sync outputs, as well as single-start and hold inputs. Step sweep is provided to switch between two frequencies for testing the response of systems to sudden changes in frequency.

Sub-synthesizer (3940 only)

In addition to the main synthesizer, the 3940 has a sub-synthesizer that generates five waveforms (∿, ⋀, ⊓⊔, ⟋|, and |⟍) from 0 to 100 kHz. The sub-synthesizer can either be used as an independent synthesizer, or as a timing oscillator to trigger and generate gates and burst oscillations in the main synthesizer. Together, the main and sub-synthesizer can become a two-phase oscillator (both synthesizers at the same frequency with a set phase difference) or a harmonic generator (with a set integer ratio between frequencies).

For more flexibility, several 3940s can be synchronized to maintain accurate phase relationships. This enables the unit to perform in a wide range of applications, including generation of 3-phase AC signals and multipoint vibration stimulus.

Trigger/Burst/Gate Oscillation

The gate mode provides continuous oscillation (of an integral number of cycles) when the trigger (gate) signal is on. In the burst mode, after the trigger signal is detected, oscillation is made for a set number of cycles (1 to 65,536). In the Model 3930A, a built-in timing generator with a period of 1μs to 2999.9s, and an accuracy of ±50ppm enables stand-alone burst signal generation without having to use an external signal source. The Model 3940 uses the sub-synthesizer for even greater flexibility in burst generation. Start and stop phases can be set to ±360° with a resolution of 0.1°.

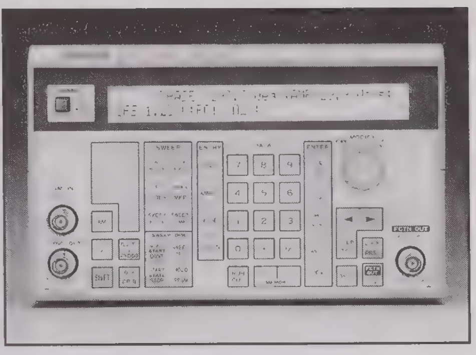
Variable Duty Cycle

For squarewaves, the duty cycle can be set from 5 to 95% with 0.1% resolution at 0.1mHz to 100kHz (3930A) or to 1MHz (3940). In the fixed duty ratio (50%) mode, the frequency range is extended to 1.2MHz (3930A) or 20MHz (3940).

AM/VCA (3930A Only)

An external signal can be used for amplitude modulation. The modulating signal can range from DC to 100kHz. Remote control of amplitude (VCA) is possible by using a DC voltage as the modulating input.

Model 3933A Phase Shifter

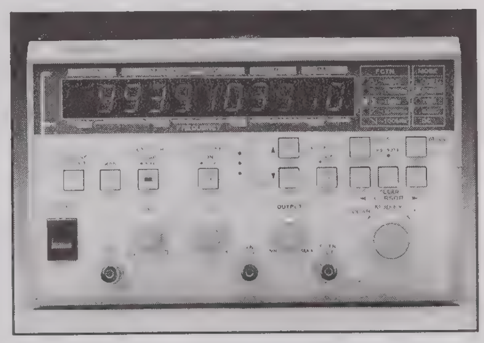


The Model 3933A Phase Shifter can be combined with the Model 3930A to configure a multiphase oscillator for use in aerospace, automotive, navigation, and energy sectors. By adding one Model 3933A for each phase, it is possible to provide up to six variable phase synchronized signals. Phase can be set to ±360° with a resolution of 0.1°. Independent settings of output voltages, waveforms, duty cycle, and phase sweep are possible for each phase.

Phase Shifter applications include:

- Stimulus signal generator for vibration tables (2 to 3 phases)
- Welding arm, spray gun, and electron beam control (2 phases)
- Electric power meter calibration
- Simulation of time-skewed signals (2 - 6 phases)

Model 3910



The Model 3910 offers the precision inherent in Direct Digital Synthesis, but at the price of a standard function generator. The frequency range is 0.1mHz to 1.0MHz for sinewaves and fixed duty cycle squarewaves, and 0.1mHz to 100kHz for triangle, variable duty cycle squarewaves, and up/down-ramping sawtooth waveforms.

Accuracy of ±30ppm is maintained over the entire frequency range. Output voltage is up to 20Vp-p.

The Model 3910 is ideal for stand-alone applications or in the rack with its optional GPIB interface. Beyond it aesthetic appeal, the front panel interface is powerful and intuitive. Controls are logically grouped by similar function, and a large 11-digit display gives clear visibility for frequency readout and instrument operation.

In addition to the continuous oscillation and DC output capability of the Model 3910, other flexible modes of oscillation are also available, including burst, trigger, and gate. In the burst mode, a programmed number of cycles are generated, followed by a given number of blank cycles. The trigger mode generates a set number of cycles upon receiving a trigger. The gate mode provides continuous oscillation when the trigger signal is on. Start and stop phases can be set to ±360° with a resolution of 0.1° for all modes.

CABLES

3949	Interconnect Cable
7051-2	BNC Interconnect Cable, 0.6m (2 ft.)
7051-5:	BNC Interconnect Cable, 1.5m (5 ft.)

RACK MOUNT KITS

3900-1	Single Fixed Rack Mount Kit
3900-2	Dual Fixed Rack Mount Kit

See page 163 for descriptions of all accessories.

Multifunction Synthesizers

SPECIFICATIONS	3910	3930A	3940
Waveform	∿, ⌃, ◿, ◺, ⎍ (Fixed 50% duty ratio), ⎍ (Variable duty ratio), DC only.		Arbitrary waveform, ∿, ⌃, ◿, ◺, ⎍ (Fixed 50% duty ratio), ⎍ (Variable duty ratio), DC only **Arbitrary waveform input:** **Arbitrary data input method:** Data input by GPIB. **Address:** 0000 to 1023. **Data:** –511 to 0 to +511.
Oscillation Modes	Continuous oscillation. **Burst:** M cycles generated, S cycles blank, where M and S = 1 to 16 in units of one cycle. **Trigger:** M cycles generated by a trigger signal, where M = 1 to 16 in units of one cycle. **Gate:** Oscillation in units of one cycle while the trigger signal is on. **DC:** DC only.	Continuous oscillation. **Burst:** M cycles generated by means of a trigger signal, where N = 1 to 65,536 (N = integer). **Gate:** N cycles generated when trigger signal is on (N = integer).	Continuous oscillation. **Burst:** M cycles generated, S cycles blank, where M and S = 0.5 to 32768.0 (multiples of 0.5). **Trigger:** M cycles generated by a trigger signal, where M = 0.5 to 32768.0 (multiples of 0.5). **Gate:** Oscillation in units of half cycles while the trigger signal is on.
Frequency Range	∿, ⎍ (50% duty ratio): 0.1mHz to 1000kHz. ⌃, ◿, ◺, ⎍ (Variable duty ratio): 0.1mHz to 100kHz.	∿, ⎍ (50% duty ratio): 0.1mHz to 1.2MHz. ⌃, ◿, ◺, ⎍ (Variable duty ratio): 0.1mHz to 100kHz.	∿, ⎍ (50% duty ratio); Continuous: 0 to 20 MHz. For burst, trigger and gate, stop level hold is 0 to 10MHz. For other, 0 to 1MHz. All arbitrary waveform data points can be continuously output up to approx. 107kHz. Beyond this frequency points are sampled.
Frequency Display (fixed)	11 digits max. 0.1mHz resolution (fixed).	11 digits max. 0.1mHz resolution (fixed).	12 digits max., resolution: 0.1mHz (fixed).
Frequency Accuracy	±30ppm.	±5ppm.	±5ppm, 20℃ ~ 30℃.
Frequency Stability		±2ppm/year.	±5ppm/year, ±0.5ppm/℃ typ. (24 hours after power on).
Setting by Period		**Setting Range:** 840ns to 10000s. **Display:** 60 digits max., minimum resolution 10ns. Oscillation is made at a frequency that is the reciprocal of the set period (digits smaller than 0.1mHz are truncated).	**Setting Range:** 40ns to 10000s. **Display:** 6 digits max., minimum resolution 1ns. Oscillation is made at a frequency that is the reciprocal of the set period (digits smaller than 0.1 mHz are truncated).
Maximum Output Voltage	**AC Only:** 20V p-p (open circuit), 10V p-p (50Ω load). **DC Only:** ±10V (open circuit), ±5V (50Ω load).	**AC Only:** 30V p-p (open circuit), 15V p-p (50Ω load). **DC Only:** ±15V (open circuit), ±7.5V (50Ω load).	**AC Only:** 20V p-p (open circuit), 10V p-p (50Ω load). **DC Only:** ±10V (open circuit), ±5V (50Ω load).
Output Voltage Display		Max. Number of Digits / Minimum Resolution AC V p-p: 3, 0.01mV p-p V rms: 3, 0.01mV rms dBV: 3 + sign, 0.1dBV (fixed) DC: 3 + sign, 0.01mV	Max. Number of Digits / Minimum Resolution AC V p-p: 3, 0.01mV p-p (open circuit), 0.01mV p-p (50Ω load) V rms: 3, 0.01mV p-p (open circuit), 0.01mV p-p (50Ω load) dBV: 3+sign, 0.1dBV (open circuit), 0.1dBV (50Ω load) dBm: 3+sign, 0.1dBm (50Ω load) DC: 3+sign, 0.01mV (open circuit), 0.01mV (50Ω load) Display switched between open circuit and 50Ω load. However, for dBm, value indicated is always the value for a 50Ω load. For an arbitrary waveform, the units are always V p-p, and the voltage corresponding to the data values –511 to +511 is displayed.
AC Amplitude Accuracy (rms values)	Variable over a 20dB span in end ranges of 20V p-p, 2V p-p, 200mV p-p and 20mV p-p.	(1 kHz) ∿ / ⌃ ◿ ◺ ⎍ 3.00V p-p to 30.0V p-p: ±0.5%, ±1 % 300mV p-p to 2.99V p-p: ±1.0%, ±1.5% 30.0 to 299mV p-p: ±1.5%, ±2.0% Up to 50kHz in continuous mode. DC offset at 0V, AM set to off, open-circuit load, duty ratio of 50% within a temperature range of of 18° to 28℃.	∿ ⎍ / Other waveforms 20.0V p-p ~ 2.01V p-p: ±2%, ±3% 2.00V p-p ~ 201mV p-p: ±4%, ±5% 200.mV p-p ~ 20.1mV p-p: ±6%, ±7% In continuous mode, up to 10kHz, with DC offset of 0V, open load, within ±5℃ of temperature when calibrated.
Amplitude vs. Frequency Characteristics ∿	Up to 10kHz ± 0.1dB Up to 1MHz + 1 dB/–3 dB	Up to 100kHz: ±0.1dB 100kHz to 700kHz: ±0.3dB 700kHz to 1MHz: +0.3dB, –0.5dB 1MHz to 1.2MHz: +0.3dB, –1.0dB	Up to 1MHz: ±0.3dB 1MHz to 7MHz: +0.3, –0.5dB 7MHz to 10MHz: +0.3, –1.0dB 10MHz to 20MHz: +0.3, –2.5dB
⎍ (Duty ratio fixed or variable set to 50%)	Up to 10kHz ± 5%	Up to 100kHz: ±2%	Up to 1MHz: ±3%
⌃	Up to 10kHz ± 5%	Up to 10kHz: ±3%	Up to 100kHz: ±3%
◿ ◺	Up to 10kHz, ± 7%	Up to 10kHz: ±5%	Up to 100kHz: ±5%
	In continous mode, 1kHz reference, DC offset set to 0V, 50Ω load, and amplitude setting of 3.0mV p-p to 20V p-p for waveforms other than ∿. (rms for ∿).	In continous mode, 1kHz reference, DC offset set to 0V, AM set to off, 50Ω load, and amplitude setting of 30.0mV p-p to 30.0V p-p for waveforms other than ∿. (rms for ∿).	In continous mode, 1kHz reference, DC offset of 0V, 50Ω load, and amplitude setting of 100mV p-p to 10V p-p for waveforms other than ∿. (rms for ∿).

Multifunction Synthesizers

SPECIFICATIONS		3910	3930A	3940
Sinewave Spectrum Purity	Total Harmonic Distortion	Up to 100kHz: 0.3% max (typ.).	10Hz to 100kHz: 0.1% max.	10kHz to 100kHz: 0.3% max.
	Harmonics	100kHz to 500kHz: –45dBc (typ.). 500kHz to 1MHz: –40dBc (typ.).	100kHz to 500kHz: –40dBc max. 500kHz to 1.2MHz: –30dBc max. (For amplitude setting of 30.0 Vp-p).	100kHz to 20MHz: –35dBc max.
	Spurious Components	Up to 1MHz: –55dBc (typ.).	Up to 50kHz: –55dBc max. 500kHz to 1.2MHz: –40dBc max. (For amplitude setting of 30.0V p-p).	Up to 20MHz: –40dBc max.
		In continuous mode, DC offset of 0V, 50Ω load, and amplitude setting of 20V p-p.	In continuous mode, with DC offset of 0V, AM set to off, 50Ω load, and amplitude setting of 30.0mV p-p.	In continuous mode, DC offset of 0V, 50Ω load, and amplitude setting of 10.0V p-p.
Squarewave Characteristics	Rise/Fall Times	90ns (typ.).	150ns max.	8ns max. (in modes other than CONT with stop level at RESET, 15ns max.).
	Overshoot and Undershoot	5% of peak-to-peak output amplitude, max.	5% of peak-to-peak output amplitude, max.	
	Duty Ratio Accuracy (for 50% fixed duty ratio)	±1% of period (up to 10kHz).	±0.3% of period (up to 10kHz).	Up to 100kHz: ±0.3% of period. 100kHz to 1MHz: ±2% of period.
	Variable Duty Ratio	5% to 95% min. (up to 10kHz). 10% to 90% min. (up to 100kHz). **Jitter:** 0.01% of period + 20ns (typ.).	5.0 to 95% (0.1% resolution). **Accuracy:** ±0.2% of period (up to 10kHz). **Jitter:** 150ns max.	5.0 to 95% (0.1% resolution). **Accuracy:** ±1% of period (up to 1MHz). **Jitter:** 15ns max.
		In continuous mode, 50Ω load, DC offset of 0V, and amplitude setting of 10V p-p.	DC offset of 0V, AM set to off, 50Ω load, and amplitude setting of 30.0mV p-p to 15V p-p.	50Ω load, DC offset to 0V, and amplitude setting ≤100mV p-p (50Ω). The duty ratio for mode other than CONT and not during a sweep.
Output Impedance		50Ω±2%, unbalanced.	50Ω±1%, unbalanced.	50Ω, unbalanced.
Sync Output		TTL level.	TTL level.	TTL level (can be terminated with 50Ω).
Modify		The left and right keys are used to select the digit to be modified. The modify dial is used to increment and decrement in steps.		
		Step Size: ±1.	**Step Size:** ±1, ±5, ×/÷2, ×/÷10.	**Step Size:** ±1, ×/÷2, ×/÷10.
Output On/Off Switching		FCTN OUT on/off, output open when off.	FCTN OUT on/off, output open when off.	The FCTN OUT of the main and sub-synthesizers are simultaneously switched on and off, with the following conditions prevailing when off: **Main Synthesizer:** FCTN OUT: Output open. SYNC OUT: Same as on. **Sub-Synthesizer:** FCTN OUT: 0V output. SYNC OUT: Oscillation stops at hi or lo level.
Calibration				During calibration to compensate the AC amplitude and offset error of the main synthesizer, FCTN OUT is off, and SYNC OUT is in a indeterminate condition.
Signal Ground		Grounds of all input and output connectors are connected to the case.		
Setting Memory		1 set	10 sets, battery backed up.	10 sets, battery backed up.
Lock			When in the locked condition, parameter setting changes and operational status changes by means of panel keys are not accepted, but it is possible to display all current parameter values.	
GPIB Interface		Optional	Built-in	Built-in
		Functions: SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT0, C0. **Data:** 7-bit ISO (ASCII) code. **Delimiter** - for sending: CR or CR/LF. For 3930A and 3940: Selectable by numeric keys on the front panel; EOI also sent simultaneously. - for receiving: CR, CR/LR, CR plus EOI, CR/LF plus EOI, or EOI only. **Address:** 0 to 30 (input by numeric keys on the front panel).		
Power Requirements		AC 100, 120, 220, or 240V ± 10% switchable (AC 250V max.), 48 to 62Hz.		
Power Consumption		Approx. 20 VA	Approx. 34 VA	Approx. 70 VA
Environment		**Operating:** 0 to 40°C, 10 to 90% humidity. **Storage:** –10 to +50°C, 10 to 80% humidity.		
Dimensions		216mm wide × 132.5mm high × 350mm deep (8½ in. × 5¼ in. × 13¾ in.).		
Weight		Approx. 3.2 kg	Approx. 4.6 kg	Approx. 5.6 kg

FREQUENCY SWEEP	3930A	3940
Sweep Type	Repeated/single, linear/log/step, reciprocating/single-direction, increasing/decreasing.	
Maximum Upper Frequency	Same as for normal oscillation .	
Minimum Lower Frequency	Linear/step: 0.1mHz; log: 10mHz.	
Minimum Sweep Width	Linear/step: 0.1mHz; log: 1 decade.	Linear/step: 0.1mHz; log: 1 octave.
Sweep time	5ms to 9999s, maximum 4 digits, minimum resolution 1ms. For 3930A in log sweep, minimum time required for one decade is 5.16ms.	
Sweep range setting method	Start and stop frequencies, or center and span frequencies are specified.	
Signal start input	TTL level: Start at rising edge; minimum pulse width: 50ns.	
Hold input	TTL level: Low: interrupts; High: restarts.	
Sync output	TTL level: Low: Indicates sweep in the direction from start frequency to stop frequency is in progress; High: At other times.	
Marker output	TTL level: Low: During sweep when marker frequency is exceeded; High: At other times.	
X drive output	0 to + 10V (open circuit); load impedance; 10kΩ min.	
Other functions	Marker frequency setting and substitution of marker frequency into center frequency.	

Multifunction Synthesizers

BURST/TRIG/GATE	3910	3930A	3940
Trigger Source		INT: Internal trigger oscillator.	INT: Synchronized to sub-synthesizer output (positive/negative logic, switchable).
	EXT: External signal. Manual trigger and remote trigger via GPIB are also possible.		
Internal Trigger Oscillator		**Period:** 0.001ms to 2999.9s. **Accuracy:** ±5 × 10^{-5}, also settable as a frequency (digits smaller than settable resolution are truncated). **Duty Ratio:** 50%. **Internal Trigger Output:** TTL level.	Refer to section on sub-synthesizer.
External Trigger Input	TTL level; minimum pulse width: 200ns.		TTL level; minimum pulse width: 50ns.
Trigger Delay	1.3μs; Jitter: 150ns.	Approx. 600ns; Jitter: 150ns.	200ns max. between external trigger input and waveform output, 100ns max. between sub-synthesizer SYNC OUT and waveform output; Jitter: 50ns max.
Start/Stop Phase	**Setting Range:** –360° to +360°; resolution: 0.1° (fixed).		**Setting Range:** –360° to +360°; resolution: 0.1° (fixed). After starting from the set phase level oscillation is made for the specified number of cycles (settable in units of 0.5 cycles), and return is made immediately to the start level. In the CONT mode also, the Ø SYNC key can be used to restart oscillations from the set phase.
Stop Level			HOLD: Stops at the oscillation start phase. RESET: Stops at the center value of the waveform.

AM INPUT (3940)

SENSITIVITY: 100% modulation at ±1V. With AM off (0V), the output amplitude is halved. Carrier-suppressed modulation is possible by adding –1V.

INPUT VOLTAGE RANGE: –3V to +1V. **MODULATION RANGE:** 100% min.

MODULATION SIGNAL BANDWIDTH: DC to 100kHz.

CARRIER SIGNAL: Up to 100kHz ∿. **INPUT IMPEDANCE:** 10kΩ.

SUB-SYNTHESIZER (3940)

WAVEFORMS: ∿, ⋀, ⊿, ◺, ⊓.

FREQUENCY RANGE: 0 to 100kHz, resolution: 0.1mHz (fixed).

FREQUENCY ACCURACY: Same as main synthesizer (common clock generator).

SETTING BY PERIOD: Oscillation is made at a frequency that is the reciprocal of the set period (rounded off to the nearest 0.1mHz).

OUTPUT VOLTAGE: 0.2V p-p (open circuit) to 20V p-p (open circuit).

OUTPUT VOLTAGE DISPLAY:

DISPLAY	MAX. NO. OF DIGITS	RESOLUTION (open circuit, fixed)
Vp-p	3	0.1V p-p
Vrms	3	0.1V rms
dBV	3 + sign	0.1dBV

AMPLITUDE ACCURACY: ∿: ±3% (rms). ⋀, ⊿, ◺, ⊓: ±3% (rms).
At a frequency of 1kHz, 5V p-p (open circuit) or greater

SINEWAVE AMPLITUDE vs. FREQUENCY CHARACTERISTICS:
10Hz to 50kHz: ±0.3dB (rms). **50kHz to 100kHz:** +1.0dB, –2.0dB (rms).
(1kHz reference frequency, amplitude setting of 2V p-p (open circuit) min., and open load.)

SINEWAVE TOTAL HARMONIC DISTORTION:
10Hz to 5kHz: 0.2% max. **5kHz to 100kHz:** 0.3% max.
(At amplitude setting of 20V p-p (open circuit), load open.)

OUTPUT IMPEDANCE: Approx. 600Ω, unbalanced.

LOAD IMPEDANCE: 10kΩ max.

SYNC OUTPUT: TTL level.

PHASE*: –360° to +360°, 0.1° resolution (fixed).

*When used alone or as a master unit, if the Ø SYNC key is pressed or GPIB "SYN" command issued, this is the phase at which oscillations are restarted.

When operating as a slave, if the Ø SYNC key of the master is pressed or GPIB "SYN" command issued, this is the phase at which oscillation is restarted.

EXTERNAL SIGNAL SUMMING (3940)

FUNCTION: An external signal input is added to main synthesizer waveform output.

GAIN AND MAXIMUM INPUT VOLTAGE:

Vo-p	Gain	Maximum Input Voltage (V)
1V to 10V	1	10–Vo-p
100mV to 1V	1/10	10–10xVo-p
10mV to 100mV	1/100	10–100xVo-p
1mV to 10mV	1/1000	10–1000xVo-p

Vo-p: Open-circuit value for the set zero peak value (AC/2 + |DC|), with the gain for a 50Ω load being ½ of the above value.

OUTPUT IMPEDANCE: Approx. 100kΩ.

FREQUENCY RANGE: DC to 1MHz.

SYNC/MULTIPHASE OPERATION (3940)

FUNCTION: A single 3940 (master) can send clock pulses and Ø SYNC pulses to a number of other 3940s (slave units) to synchronize them. It is possible, however, to individually set waveforms, amplitudes and frequencies.

NUMBER OF UNITS CONNECTABLE: One master unit can be connected to up to three slaves, using Model 3949 interconnect cable.

CLOCK AND øSYNC PULSE DELAY TIME: 10ns max. for each unit.

DELAY TIME FROM øSYNC PULSE TO WAVEFORM OUTPUT:
Main synthesizer: ∿, ⊓ (variable duty ratio, fixed 50%): 120ns max.
For Other Waveforms: 80ns max. **Jitter:** 15ns max.
Sub-Synthesizer: ∿: 3μs max. **Other Waveforms:** 2μs max. **Jitter:** 350ns max.

PHASE: Setting Range: –360° to +360°; resolution: 0.1° (fixed).
When the master øSYNC key is pressed or the GPIB "SYN" command is issued, oscillation is restarted from the various set phases. Common with the start phase for burst/trigger/gate oscillation.

3933A (Phase Shifter for Multiphase Operation of the 3930A)

OSCILLATION MODE FREQUENCY: Mode set at the 3930A.

PHASE SETTING RANGE: –360 to +360° (value with respect to the 3930A start/stop phase 0°), 4-digit + sign display; resolution: 0.1% (fixed).

PHASE ACCURACY: ∿: (0.1° + 120 ns) + D
⊓ (Rise time): Duty ratio: 50% fixed ± (0.5° + 120ns) + D
Variable ± (0.1° + 220ns) + D
⋀ : ±(0.1° + 90 ns) + D
⊿ (fall time), ◺ (rise time): ± (0.1° + 240ns) + D.
D = +0, –(n–2) × 40ns.
In a cascade connected system, phase number n is as follows:

3930A → 3933A → 3933A . . .
n=1 n=2 n=3 n ≤ 6 (i.e. maximum of 6 phases).

Accuracy is with respect to (3933A phase setting) – (3930A start/stop phase setting). Both 3930A and 3933A are set as follows: DC offset of 0V, AM off, 50Ω load, same waveform, 18 to 28°C. The squarewave duty ratio is fixed for both, or variable for both (arbitrary duty ratio. CONT mode amplitude setting of 30.0mV p-p to 30.0V p-p independent setting possible.

PHASE SWEEP:
Sweep Type: Repeated/single, linear/step, reciprocal/single-direction, rising/falling.
Sweep Range: –360° to 360°. **Minimum Sweep Width:** 0.1°.
Sweep Time: 5ms to 9999s, 4 digits max., minimum resolution of 1ms.
Sweep Range Setting Method: Start and stop or center and span phases are set.
Single Start Input: TTL level, start at rising edge, minimum pulse width: 50ns.
Hold Input: TTL level, Low: interrupts; High: restart.
Sync Output: TTL level, Low: Sweep in progress from start phase to stop phase High: At other times.
Marker Output: TTL level, Low: During sweep when marker phase is exceeded. High: at other times.
X Drive Output: 0 to +10V (open circuit); load impedance: 10kΩ min.
Other Functions: Marker phase setting and substitution of marker phase into center phase.

SIGNAL GROUND: All inputs and outputs except the waveform output, sync output, and AM input have connector grounds connected to the case.

POWER CONSUMPTION: Approx. 38VA. **WEIGHT:** Approx. 4.6kg.

Other specifications are the same as 3930A.

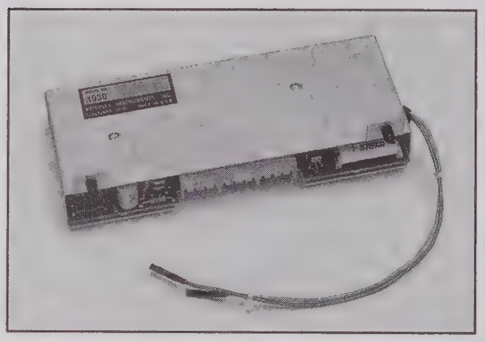
Accessories

DMM Function Options 164
Interfaces and Outputs 165
IEEE-488 Interface Cards & Software 167
Test Leads & Probes 172
Cables 176
Connectors & Adapters 183
Test Fixtures 191
Calibration, Maintenance, Spare Parts 196
Power 199
Rack Mount Kits 200
Carrying Cases 204

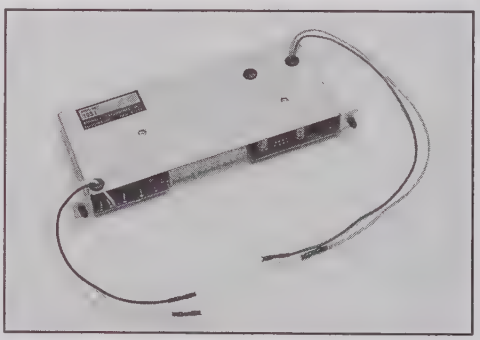
DMM Function Options

MODEL	NAME	USE WITH:
1930	TRMS ACV Option	193A
1931	Current Option	193A
1944A	Second Channel	194A
1950	DCA, TRMS ACV and ACA Option	195A
1992	8-Channel Scanner Option	199

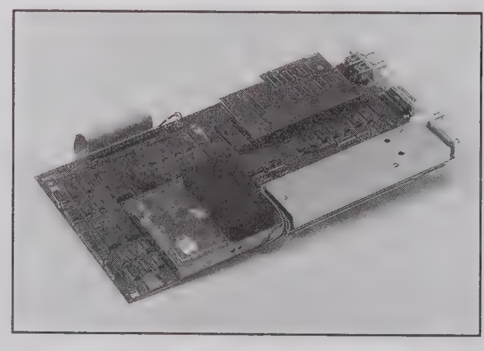
Model 1930 TRMS AC Volts Option: A True Root Mean Square (TRMS) AC plug-in option for Model 193A. The 1930 enables the 193A to measure the TRMS value of an AC signal. An AC+DC function is included. The 1930 has four ranges from 2V to 1000V.



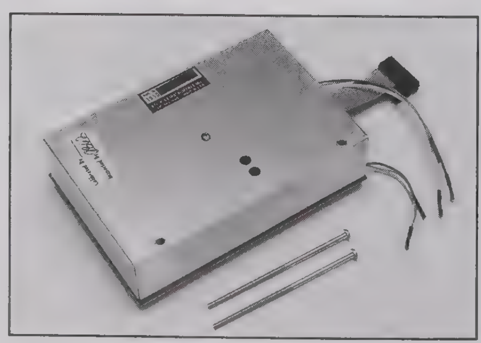
Model 1931 Current Option: The 1931 adds 5 ranges of current with autoranging capability to the Model 193A. The option is field installable and will measure AC currents when the 1930 is also installed.

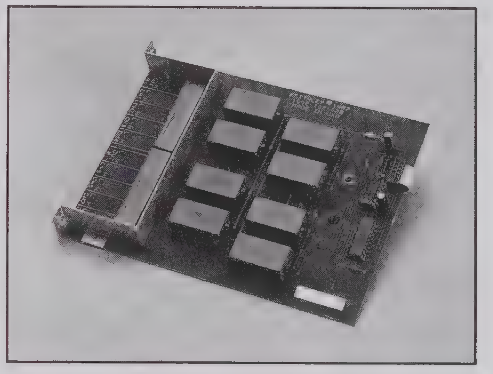


Model 1944A Channel 2 Option: Provides dual channel operation for Model 194A. Second channel is entirely independent of the first. Provides 16-bit resolution sampling up to 100kHz (8-bit up to 1MHz) with 64k byte memory.



Model 1950 AC Voltage, AC and DC Current Option: Allows Model 195A to measure TRMS AC voltage from 1μV to 700V, TRMS AC current from 1nA to 2A, and DC current from 100pA to 2A. The 1950 plugs into the 195A for easy installation. Field installation requires recalibration of the 195A.





Model 1992 8-Channel Scanner: Installs in the 199 System DMM/Scanner to provide switching and measurement in one instrument.

Contact Configuration: 8-channel 2-pole or 4-channel 4-pole. Break-before-make.

Contact Potential: <1μV per contact pair.

Connector Type: Quick disconnect screw terminals, #14 AWG maximum wire size.

Maximum Signal Level: 200V peak, 100mA, resistive load.

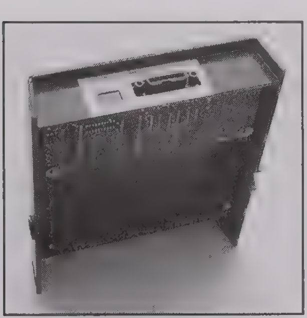
Dimensions, Weight: 25mm high × 130mm wide × 170mm deep (⅞ in. × 5 in. × 6½ in.). Adds 0.3kg (8 oz.) to Model 199.

Accessory Supplied: Model 1993 Quick Disconnect Scanner Connector Kit

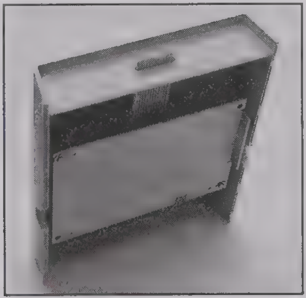
For complete specifications, see Model 199 System DMM/Scanner, page 30.

Interfaces and Outputs

MODEL	NAME	USE WITH
1753A	IEEE-488 Interface	175A
1792	Isolated BCD Output	177, 179A, 480
1793	Isolated IEEE-488 Output	177, 179A, 480
1972A	IEEE-488 Interface with Analog Output	197A
1973A	IEEE-488 Interface	197A
2243	IEEE-488 Interface	224
3913	IEEE-488 Interface	3910
4853	IEEE-488 Interface	485
5802	Isolated Analog Output/IEEE-488 Interface	580
6422	Isolated BCD Output	642
6423	Isolated IEEE-488 Output	642

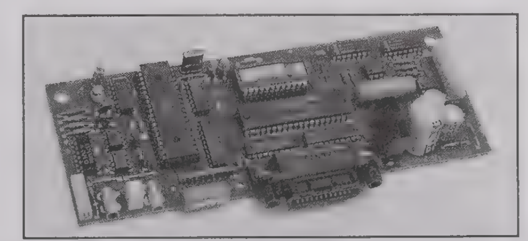


Model 1753A IEEE-488 Interface: Adds extra versatility to the Model 175A by allowing the transmission of data and commands over the IEEE-488 bus using standard IEEE-488-1978 protocol. The 1753A is field installable (the 175A must then be recalibrated).

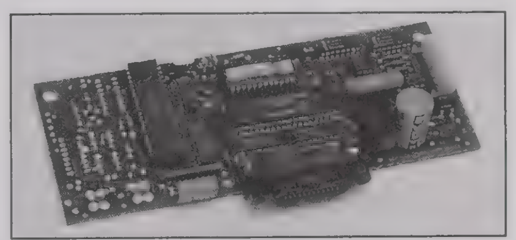


Model 1792 Isolated BCD Output: Converts reading to electrically isolated, latched, and buffered parallel BCD format. Output data include sign, overrange, busy. Use with 177, 179A, 480.

Model 1793 IEEE-488 Output: Converts readings to IEEE-488 compatible outputs for automatic data gathering. Output includes 4½-digit ASCII data sign and overrange. TLK ONLY or ADDRESSABLE modes. Use with 177, 179A, 480.



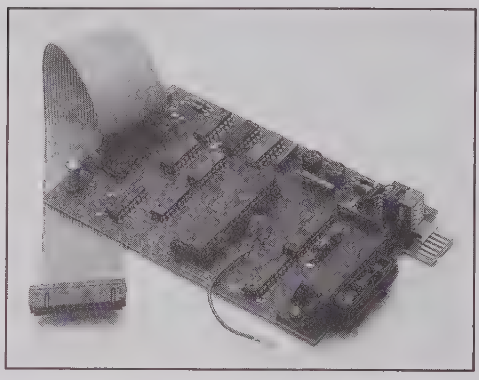
Model 1972A Analog Output/IEEE-488 Interface: Includes all logic to interface the Model 197A to the IEEE-488 bus. Contains an isolated analog output with selectable gain. The analog output can be selected to represent the value in the A/D converter or data stored in the internal memory.



Model 1973A IEEE-488 Interface: Adds extra versatility to the Model 197A DMM by allowing the transmission of data and commands over the IEEE-488 bus using standard IEEE-488-1978 protocol.

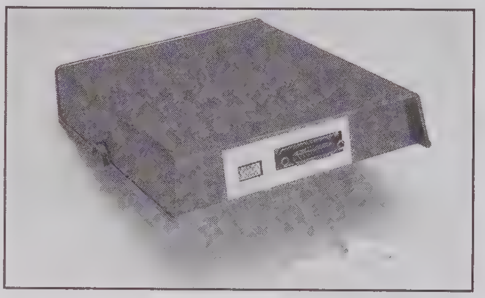
Interfaces and Outputs

Model 2243 IEEE-488 Interface: Adds extra versatility to the Model 224 by allowing the transmission of data and commands over the IEEE-488 bus. The 2243 incorporates a separate digital I/O port that may be used to monitor and control external logic.

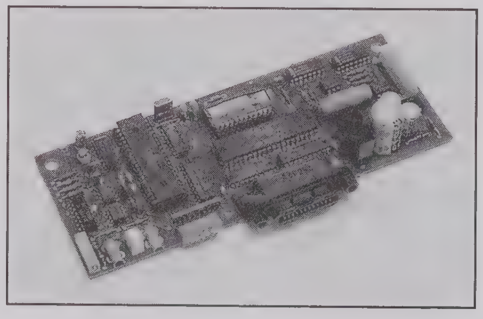


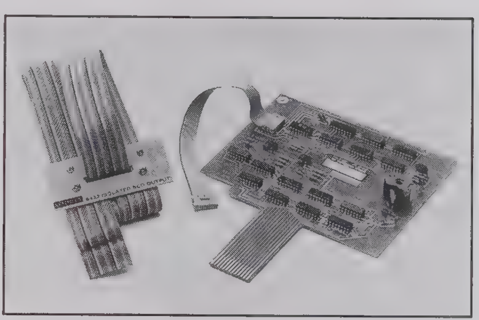
Model 3913: IEEE-488 interface for Model 3910 Function Synthesizer.

Model 4853 IEEE-488 Interface: Adds extra versatility to the Model 485 Picoammeter by allowing the transmission of data and commands over the IEEE-488 bus using standard IEEE-488-1978 protocol.

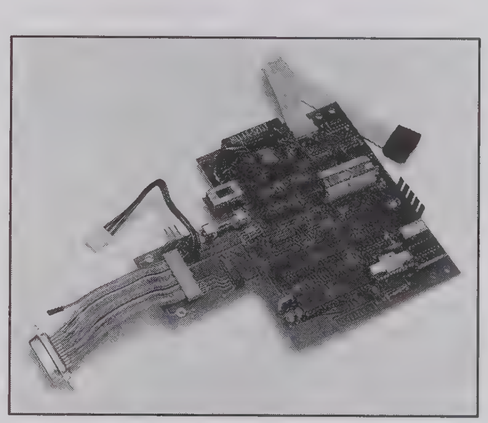


Model 5802: Isolated analog output/IEEE-488 interface for Model 580.





Model 6422 Isolated BCD Output: Converts the displayed reading on Model 642 to an electrically isolated, latched, and buffered parallel BCD format. Additional data lines include sign, overrange, and busy.



Model 6423 Isolated IEEE-488 Output: Provides the logic and control functions necessary to interface Model 642 to an IEEE-488 bus.

IEEE-488 Interface Cards & Software

Interfaces and Software

This section on interfaces and software describes a selection of powerful computer enhancements for building up IEEE-488 based data acquisition and automatic test systems. These products work with IBM computers and compatibles to provide dependability, simplicity, and reliability when developing test systems and test programs.

Keithley offers interfaces from Capital Equipment Corporation, IOtech, and Keithley MetraByte. Programming is direct and in any of several popular test languages. Since the software is in ROM, you simply plug the card into an available slot and begin programming.

Software utilities from CEC enhance the capabilities of the IEEE-488 hardware. For sophisticated test routines, interrupt handling software is available. Beginning programmers and those who perform simple interactive data acquisition routines will find the Co-Operator software useful. And results can be displayed graphically on either linear or logarithmic scales using CEC-GRAPH.

Keithley Asyst offers other IEEE-488 data analysis software. See page 210 for complete details.

Interface Cards Selector Guide

NAME	DESCRIPTION	COMPUTER	PAGE
CAPITAL EQUIPMENT CORPORATION			
INTERFACE CARDS			
4-488-CEC-0M	Multifunction IEEE-488 Interface Card	IBM PC-AT, compatibles	168
4-488-CEC-1M	Multifunction IEEE-488 Interface Card (1MB RAM)	IBM PC-AT, compatibles	168
PC-488-CEC	IEEE-488 Interface Card	IBM PC, XT, AT, compatibles	169
PS-488-CEC	IEEE-488 Interface Card	IBM PS/2 family	169
SOFTWARE			
PC-488-COP	Co-Operator™ IEEE-488 programming aid	IBM PC, XT, AT, compatibles	170
PS-488-COP	Co-Operator™ IEEE-488 programming aid	IBM PS/2 family	170
PC-488-INT	BASIC interrupt handler	IBM PC, XT, AT, compatibles	170
PS-488-INT	BASIC interrupt handler	IBM PS/2 family	170
PC-488-GRAPH	Graphics software	IBM PC, XT, AT, compatibles	170
PS-488-GRAPH	Graphics software	IBM PS/2 family	170
IOTECH			
GP488B	IEEE-488 controller board	IBM PC, XT, AT, PS/2, compatibles	171
KEITHLEY INSTRUMENTS DIVISION			
500-SERIAL	RS-232 to IEEE-488 Converter	IBM PC, XT, AT, PS/2, compatibles	171
KEITHLEY METRABYTE			
	Keithley MetraByte offers ten communications interface boards for IEEE-488, RS-232, RS-422 and RS-485 applications. See page 208 for more information or return the reply card in the back of this catalog for a complete Keithley MetraByte catalog.		

IEEE-488 Interface Cards & Software

- **Engineering multifunction products for the IBM PC-AT and compatibles**

ORDERING INFORMATION

4-488-CEC-0M
Multifunction IEEE-488 Interface Card

4-488-CEC-1M
Multifunction IEEE-488 Interface Card with 1MB RAM

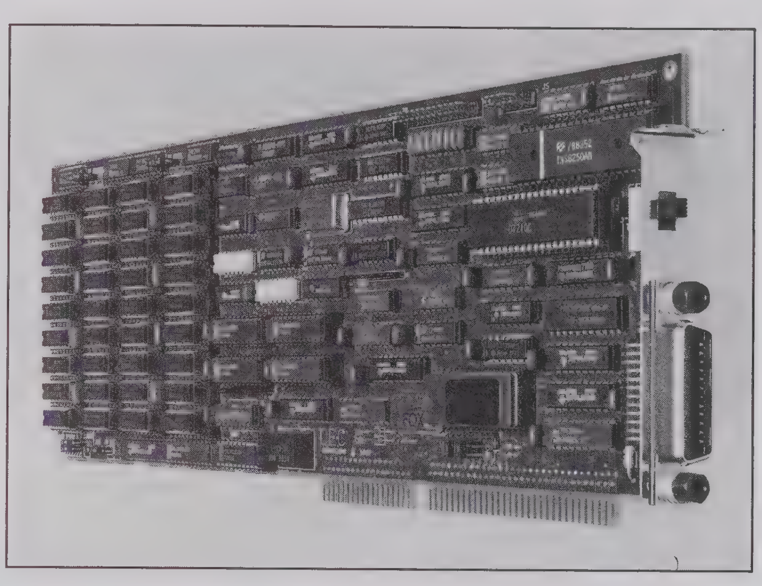
See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

HARDWARE/SOFTWARE COMPATIBILITY

4-488-CEC may be used in an IBM PC/AT or equivalent. 4-488-CEC may be used with the Intel Above Board. 4-488-CEC is compatible with any program that uses extended or expanded memory as well as all popular data acquisition programs.

4-488-CEC-0M
4-488-CEC-1M

The 4-488-CEC-0M combines IEEE-488 instrument control with an RS232 serial port, parallel port, and user-configurable memory space: up to 1 MB using 256k DRAMs or 4 MB using 1MB DRAMs. (A 1 MB version, Model 4-488-CEC-1M, is available with 256kB DRAMs installed.) The 4-488-CEC is designed to handle large CAE and data acquisition tasks at high speed.



Power Memory

The 4-488-CEC offers conventional, expanded, and extended (OS/2) memory. Expanded memory eliminates the 640k barrier by supporting the Lotus/Intel/Microsoft expanded memory specification.

Programming

Instrument programming is handled through resident firmware that supports IEEE-488 extensions to BASIC, Pascal, C, and Fortran. The RS232 port allows either DTE or DCE operation to eliminate cabling problems.

Software

Software is included for automatic (switchless) installation, configuration, and comprehensive testing. Memory management software permits allocation of conventional, expanded, or extended memory in any 128kB increment. An extensive software library provides immediate answers for most instrument and peripheral control problems.

HARDWARE

MEMORY: Up to 4MB of 16-bit RAM on one board. User configurable for 256kB or 1MB DRAMs. 256kB DRAMs provide a maximum of 1MB. 1MB DRAMs provide a maximum of 4MB. Supports expanded, extended, and conventional memory combinations.

EXPANDED MEMORY: Supports expansion of the 640kB address space to over 4MB (8MB with two boards) using the Lotus/Intel/Microsoft expanded memory specification.

EXTENDED MEMORY: Supports memory extensions to 4, 8, 12, or 16MB using one or more boards. This memory may be used for RAM disks or programs capable of protected mode addressing.

CONVENTIONAL MEMORY: Brings PC/ATs with 512kB RAM up to a full 640kB.

IEEE-488: The IEEE-488 port supports all IEEE-488 commands. System controller and device modes are programmable. Interrupt channel is selectable. Direct memory access may be enabled or disabled. Resident firmware extends your programming languages to include all IEEE-488 functions.

RS232 SERIAL PORT: User configurable for DTE or DCE operation to eliminate cabling problems.

PARALLEL PORT: IBM compatible (Centronics) parallel printer port.

CONNECTORS: Standard IEEE-488 connector, 9-pin (IBM standard) RS232 connector, and 25-pin parallel port connector included for fast installation.

SOFTWARE

MEMORY MANAGEMENT: Memory management software implements the Lotus/Intel/Microsoft (LIM) expanded memory specification. Will run any program that uses the LIM specification.

IEEE-488: Languages supported include:

BASIC - interpreted or compiled
QuickBASIC, TBASIC, True BASIC, and Better BASIC
Pascal - Microsoft Pascal and Turbo Pascal
C - Microsoft C, Lattice C, Turbo C, DeSmet C
FORTRAN - Microsoft FORTRAN and RM FORTRAN

Supports all popular data acquisition programs. Can emulate Tektronix and Hewlett Packard controllers. Application programs for many popular instruments are included on disk (source code).

PERIPHERAL SUPPORT: Supports word processing, spreadsheet, and CAD program output to parallel, serial, and IEEE-488 peripherals.

DOCUMENTATION: IEEE-488 tutorial, programming and technical reference manual, application program library on disk.

IEEE-488 Interface Cards & Software

PC-488-CEC

for the IBM PC, XT, AT, and compatibles

PS-488-CEC

for the IBM PS/2 family

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PC-488-CEC
IEEE-488 Interface Card (IBM PC, XT, AT, and compatibles)

PS-488-CEC
IEEE-488 Interface Card (IBM PS/2 family)

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

Speaks Your Language

PC/PS-488-CEC IEEE-488 interfaces support all of the popular programming languages including interpreted and compiled BASIC, TBASIC™ , Microsoft® Pascal, Turbo® Pascal, Microsoft® C, Lattice™ C, DeSmet™ C, Microsoft® FORTRAN, and assembly language. And your investment won't become obsolete—PS-488-CEC's design allows support for new languages to be added quickly and easily.

Ready to Run

To improve your productivity, PC/PS-488-CEC software is packaged in read-only memory. This means the entire system is ready to run as soon as you turn on the power.

Serial and Parallel Polling

High-level commands support all polling functions.

HARDWARE

COMPUTERS: PC-488-CEC is compatible with IBM PC, XT, AT, compatibles, or clones. PS-488-CEC will work with the IBM System 2 models 50, 60, and 80.

DIRECT MEMORY ACCESS: Programmable DMA arbitration level. Programmable DMA enable and disable. Transmit and receive up to 64kB arrays. 16 level DMA arbitration logic.

INTERRUPTS: 14 maskable interrupts including service request (SRQ), interface clear, and device trigger. Programmable interrupt enable and disable. The interrupt request line is programmable for high or low priority.

ARCHITECTURE: An NEC 7210 provides the hardware interface between the computer and IEEE-488 bus. On-board memory and I/O addresses are programmable for automatic (switchless) installation.

PS-488-CEC can be either a system controller or a device.

CABLING: Accepts standard IEEE-488 cables.

DOCUMENTATION: IEEE-488 tutorial, programming and technical reference manual, application program library on disk.

SOFTWARE

SOFTWARE LIBRARY: Over 20 programs are included for instruments from major manufacturers.

COMMANDS: All IEEE-488 commands are supported, including Listen, Talk, Device Clear, Group Execute Trigger, Go to Local, Interface Clear, Local Lockout, Parallel Poll Configure or Disable, Remote Enable, Selected Device Clear, Serial Poll, Pass Control, Take Control, Unlisten, and Untalk. Commands and data can be combined in a single statement (macro-commands) and assigned a user defined name. Macro-commands and data transfer statements are supported in all languages.

ADDRESSING: Listen or talk to any device at any address. IEEE-488 address is programmable.

IEEE-488 Interface Cards & Software

- Interactive IEEE-488 control
- Automatic BASIC program generation
- Coding examples for PC/PS-488-CEC languages
- Device status shown on screen
- Extensive help screens

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PC-488-COP
for the IBM PC, XT, AT, and compatibles

PS-488-COP
for the IBM PS/2 family

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

Interactive Co-Operator

PC-488-COP
for the IBM PC, XT, AT, and compatibles

PS-488-COP
for the IBM PS/2 family

Think of Co-Operator as your assistant in IEEE-488 control programming. Co-Operator presents you with all the choices, and visually leads you through the control sequence. Then, at the touch of a write code key, Co-Operator produces a fully commented BASIC program.

Flexible. Some "easy-to-use" software is simple because it limits what you can do. Co-Operator gives you the full power of the industry standard IEEE-488 interface.

The Perfect Partner. Co-Operator works with the PC/PS-488-CEC interface cards to make your job easier.

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PC-488-INT
for the IBM PC, XT, AT, and compatibles

PS-488-INT
for the IBM PS/2 family

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

Interrupt Handler

PC-488-INT
for the IBM PC, XT, AT, and compatibles

PS-488-INT
for the IBM PS/2 family

Now you can have all the power of a dedicated IEEE-488 controller at a small fraction of the price. When used with the PC/PS-488-CEC, PC/PS-488-INT BASIC Interrupt Software gives you all of these features:

- BASIC subroutine processing for any IEEE-488 interrupt
- BASIC statements to enable and disable IEEE-488 interrupts
- BASIC functions to determine IEEE-488 interrupt status
- The ability to log and selectively execute interrupts
- Programmable interrupt line selection
- Compatibility with all other interrupt functions (timer, keyboard, disk, and I/O)

PC/PS-488-INT Interrupt Software is easy to learn, easy to use, and powerful.

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PC-488-GRAPH
for the IBM PC, XT, AT, and compatibles

PS-488-GRAPH
for the IBM PS/2 family

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

Graphics

PC-488-GRAPH
for the IBM PC, XT, AT, and compatibles

PS-488-GRAPH
for the IBM PS/2 family

Easy Data Display

PC/PS-488-GRAPH produces a complete graph of any data with a single command. Graphs are fully and automatically labelled, and may be displayed on the screen or drawn on a pen plotter.

Easy Data Formatting

PC/PS-488-GRAPH converts numeric data from the format your IEEE-488 or RS232 instrument supplies to a format your PC can understand.

Powerful Programming Features

PC/PS-488-GRAPH is an easy-to-use set of graphics subroutines you can use with any of the popular programming languages (BASIC, Pascal, FORTRAN, C). It provides the ability to reformat and graph data, including data obtained from instruments with the PC/PS-488-CEC interface (not required).

Linear, Log/Log, Semi Log Graphics

Data can be displayed in any of these convenient engineering formats. Axes are automatically scaled.

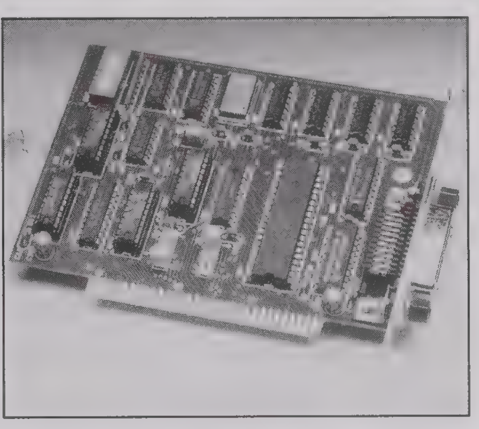
Perfect for IEEE-488 Data Acquisition

PC/PS-488-GRAPH and our PC/PS-488-CEC interface cards make a great team. Many IEEE-488 applications involve obtaining data in one format, converting to another, and displaying the data. As an example, a Nicolet digitizing oscilloscope sends data as 16-bit integers, but the bytes are in the reverse order from that used on the PC. PC/PS-488-CEC-GRAPH can convert these values to regular integers or floating point numbers for processing, then graph them on the screen or paper.

IEEE-488 Interface Cards & Software

GP488B IEEE-488 Board

The GP488B provides full IEEE-488 capability for IBM PC and compatible computers. It is a short-slot board that includes built-in DMA for high-speed data transfer, 6 selectable interrupt channel, and 4 selectable I/O addresses. Special circuitry on the board allows multiple boards within the same computer to share the same valuable DMA and interrupt channels.



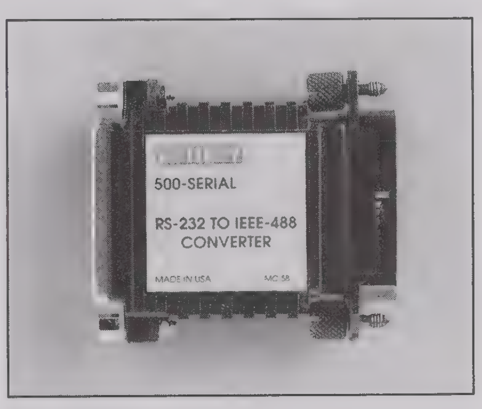
ORDERING INFORMATION

GP488B
IEEE-488 Interface Card (IBM PC, XT, AT, PS/2 and compatibles)

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

500-SERIAL

RS-232 to IEEE-488 converter for control of up to 8 GPIB instruments from any computer with an RS-232 port. Only 2 in. × 2½ in. and requires no external power connection. Supports x on/x off protocol and hardware handshaking at rates up to 19200 baud. Includes 15 ft. serial cable and utility software for MS-DOS PCs.



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500-SERIAL
RS-232 to IEEE-488 Converter (IBM PC, XT, AT, PS/2 and compatibles)

See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

COMMUNICATION INTERFACES FOR IEEE-488, RS-232/RS-422 AND RS-485

The Keithley MetraByte family of communication interface boards is offered for use with IBM PC/XT/AT, IBM PS/2 and MicroChannel computers. Our family contains ten boards for IEEE-488, RS-232, RS-422 and RS-485 communication applications. These boards are designed for instrument test systems, printer and plotter interface, and automated laboratory test set-ups. The boards are supplied with software utilities and full function drivers. Product features of the communication interface board family include Interrupt, DMA and Normal transfer modes, full compatibility with IEEE-488-1978 specifications, and direct plug-in capability.

See page 206 for more information on Keithley MetraByte products.

Test Leads and Probes

MODEL	NAME	USE WITH
1301	Temperature Probe	DMMs
1600A	High Voltage Probe	DMMs
1651	50-Ampere Shunt	DMMs
1681	Clip-On Test Lead Set	DMMs
1682A	RF Probe	DMMs
1683	Universal Test Lead Kit	DMMs
1685	Clamp-On Current Probe	DMMs
1691	General Purpose Test Leads	DMMs
1751	Safety Test Leads	175A, 196, 197A, 193A, 199 DMMs
1754	Safety Universal Test Lead Kit	175A, 196, 197A, 193A, 199 DMMs
2503	Static Detector Probe	610C Electrometer
3324	4-Terminal Alligator Clip Test Leads	3321, 3322 LCZ Meters
3325	Kelvin Clip Test Leads	3321, 3322 LCZ Meters
3326	Chip Component Test Leads	3321, 3322 LCZ Meters
5804	General Purpose, 4 Terminal Test Lead Set	580, DMMs
5805	Kelvin Probes, 0.9m (3 ft.)	580, DMMs
5805-12	Kelvin Probes, 3.6m (12 ft.)	580, DMMs
5806	Kelvin Clip Leads	580, DMMs
5807-7	Helical Spring Point Test Leads, 2.1m (7 ft.)	580, DMMs
6101A	Shielded Probe	602, 614, 617 Electrometers
6103C	Voltage Divider Probe (1000:1)	602, 614, 617 Electrometers
8693	Pt RTD General Purpose Probe	195A DMM
8695	Pt RTD Surface Probe	195A DMM
8696	Pt RTD Air/Gas Probe	195A DMM

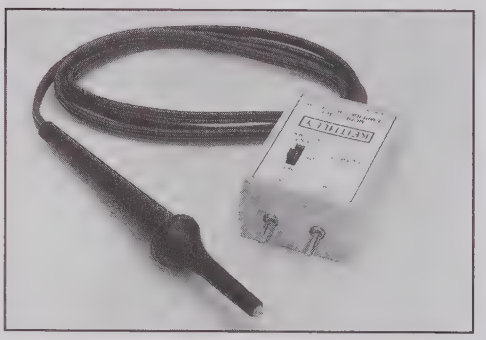
Model 1301 Temperature Probe (DMMs)

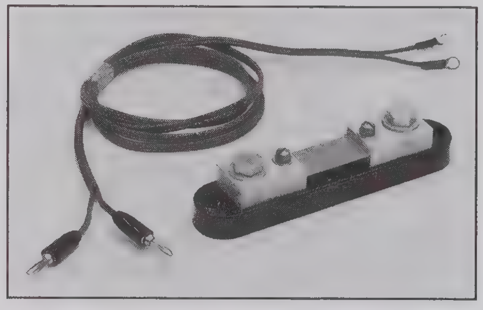
Range: –55°C to 150°C.

Output: 1mV/°C; compatible with any DMM with ≥10MΩ input impedance.

Accuracy: ±2°C from 0°to 100°C; ±3°C from –55° to 0°C and 100° to 150°C.

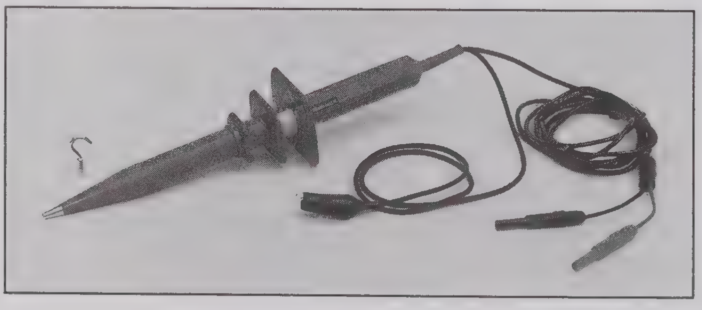
Power: 9V alkaline or C-Zn (NEDA 1604) battery; 500 hr. battery life.





Model 1651 50 Ampere Shunt (DMMs): External 0.001Ω ± 1%, 4 terminal shunt; extends current measuring capability of Keithley DMMs to 50A.

Cable Length: 1.4m (56 in.).



Model 1600A High Voltage Probe (DMMs)

Maximum Input: 40kV DC or peak AC to 300Hz.

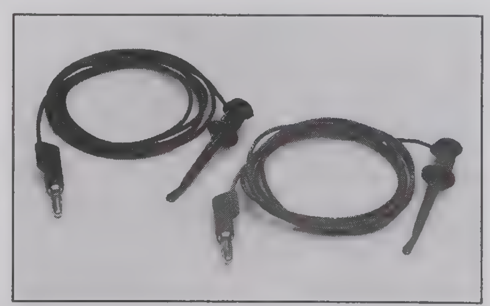
Input Resistance: 1000MΩ.

Division Ratio: 1000:1 (into 10MΩ).

Ratio Accuracy (into 10MΩ DMM): ±2.5% from 1kV to 40kV DC; –3dB at 300Hz AC.

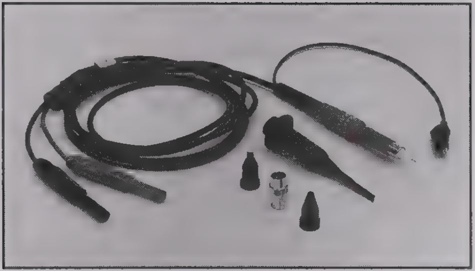
Operating Temperature: 0° to 50°C.

Cable Length: 2m (6.6 ft.).



Model 1681 Clip-On Test Lead Set (DMMs): Two 1.2m (48 in.) leads terminated with banana plugs and spring-action clip-on probes.

Test Leads and Probes



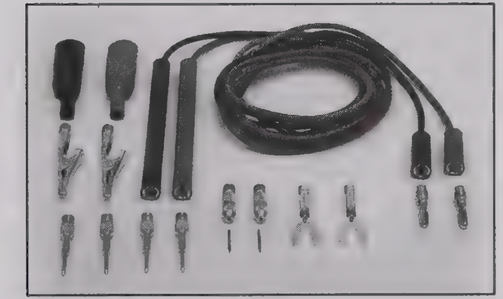
Model 1682A RF Probe (DMMs)

AC to DC Transfer Accuracy: ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in rms of a sine wave; compatible with instruments with 10MΩ input resistance.

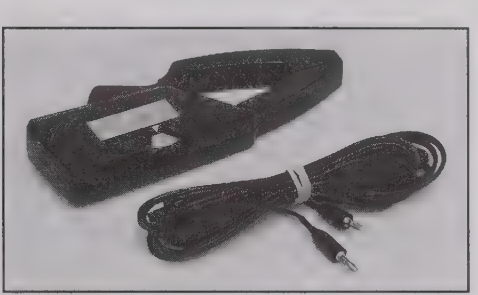
Voltage Range: 0.25V to 15V rms.

Maximum Allowable Input: 50V AC peak, 200V (AC+DC) peak.

Cable Length: 1.5m (59 in.).



Model 1683 Universal Test Lead Kit (DMMs): 14 piece test lead kit with interchangeable plug-in accessories. 2 flexible test leads, 1.2m (4 ft.), 1 red, 1 black; 2 alligator clips with boots, 1 red, 1 black; 2 banana plugs; 2 needle tips with chucks; 2 spade lugs; 4 heavy duty tip plugs.



Model 1685 Clamp-On AC Probe (DMMs): Measures AC current by clamping onto a single conductor. Interruption of the circuit under test is unnecessary. The Model 1685 detects current by sensing the changing magnetic field produced by the current flow.

Ranges: 2, 20, and 200A rms.

Accuracy: ±4% of range at 60Hz; ±6% of range at 50Hz.

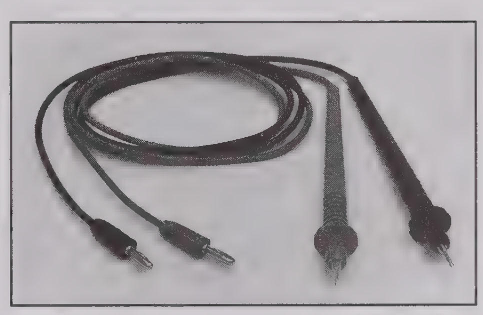
Temperature Coefficient: ±005%/°C on 20A and 200A ranges; ±0.3%/°C on 2A range.

Max. Allowable Current: 300A rms.

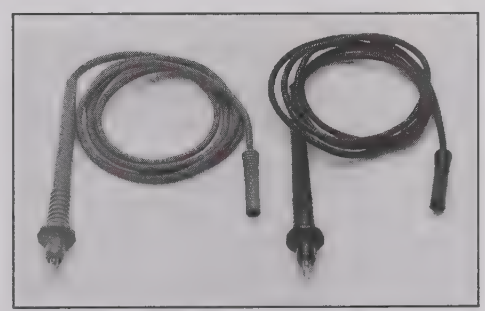
Max. Conductor Voltage: 600V rms.

Conversion Ratio: 0.1V AC/A rms.

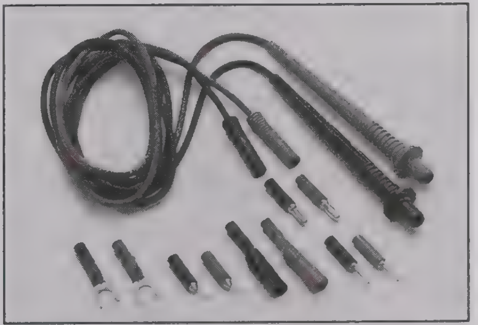
Cable Length: 3m (10 ft.).



Model 1691 General Purpose Test Lead Set (DMMs): Two 0.9m (36 in.) test leads with probe tips. Banana connection to DMM.



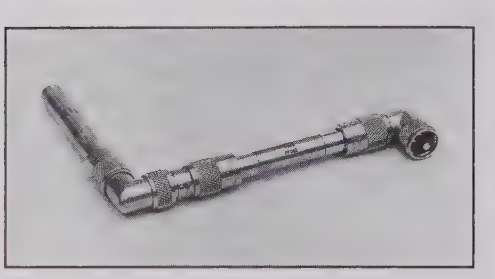
Model 1751 Safety Test Leads: 91.4cm (36 in.) test lead set supplied with each Model 175A and 197A. Finger guards and shrouded banana plugs help minimize the chance of making contact with live circuitry. Also used with Models 193A, 196, and 199.



Model 1754 Universal Test Lead Kit: 10 piece test lead kit with interchangeable plug-in accessories. Kit includes: 1 set of test leads, 91.4cm (36 in.), 1 red, 1 black; 2 spade lugs, 2 standard banana plugs, 2 hooks, and 2 miniature alligator clips with boots. For Models 175A, 193A, 196, 197A, and 199.

Test Leads and Probes

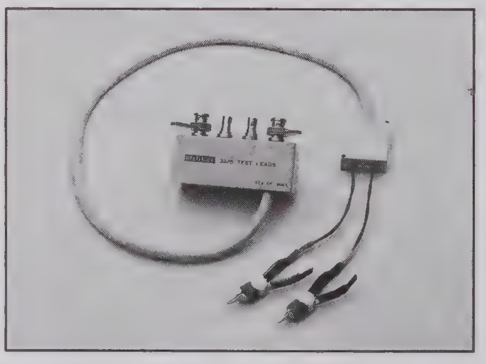
Model 2503 Static Detector Probe: Designed to detect voltage due to charge on relatively small surface areas. Solid coax 13mm (½ in.) diameter tube with 89mm (3½ in.) head, 89mm (3½ in.) coupler, 25mm (1 in.) adapter, and two 90° angle adapters which may be placed at various junctions along the tube. It gives a 10,000:1 ±10% division ratio when used with Model 610C and held 6mm (¼ in.) away from a charged plane of at least 13mm (½ in.) diameter. Output is a UHF male plug. (Use only with Model 610C.)



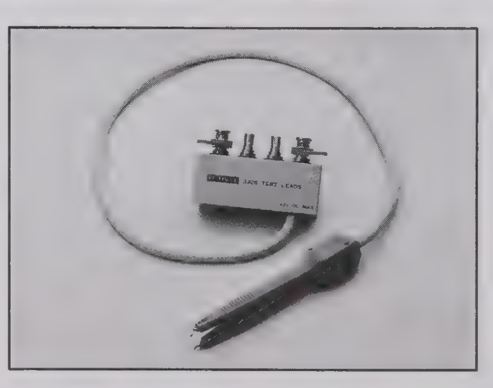
Model 3324 Four-Terminal Alligator Clip Test Leads: Designed for use with low-impedance four-terminal components in which the current-supplying terminals and voltage-measurement terminals are separated. It is also useful to connect to low-impedance circuits or sub-assemblies with separated current and voltage paths. For use with Models 3321 and 3322 LCZ Meters. Cable length 1m (3.3 ft.).

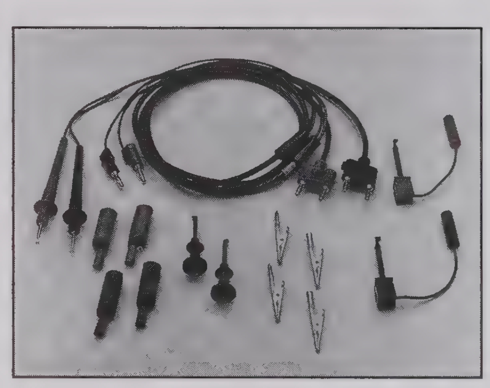
3324 TEST LEADS

Model 3325 Kelvin Clip Test Leads: Enables two clips to be used for four-terminal connections. The 3325 is used in measuring large or irregularly-shaped components which cannot be inserted into the Model 3323 direct test fixture. It can also be used as a terminal extension. For use with Models 3321 and 3322 LCZ Meters. Cable length 1m (3.3 ft.).

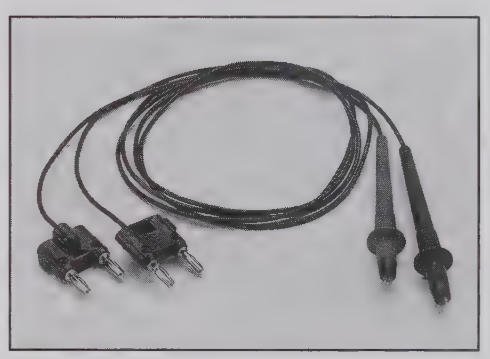


Model 3326 Chip Component Test Leads: These tweezer-type leads are designed for easy measurement of surface-mount chip components. They are also useful in determining the impedances of small pieces of material. Cable length 1m (3.3 ft.).



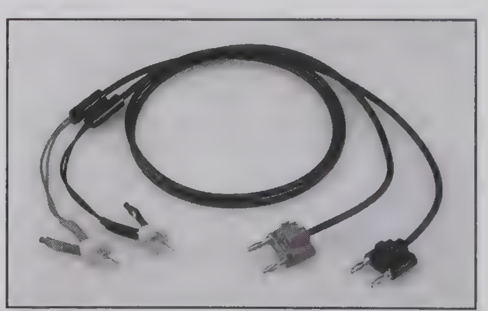


Model 5804 Test Lead Set: Designed to be used with Keithley instruments that measure 4-terminal resistance. Contains: 2 test leads, 0.9m (36 in.), red & black; 2 test clips, red & black; 2 plunger clip adapters, red & black; 2 alligator clips with boots (accept standard test probe tip); 2 alligator clips with boots (barrels accept standard banana plugs).



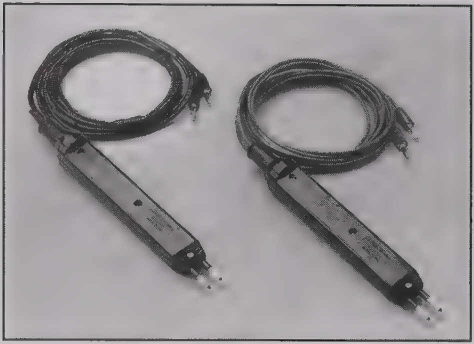
Model 5805 Kelvin Probes: 2 spring-loaded test probes, red & black, 0.9m (36 in.) with banana plug termination. Designed to be used with Keithley instruments that measure 4-terminal resistance. A package of 8 replacement contacts (P/N CS-551) is available.

Model 5805-12: Similar to 5805 but 3.6m (12 ft.) in length.

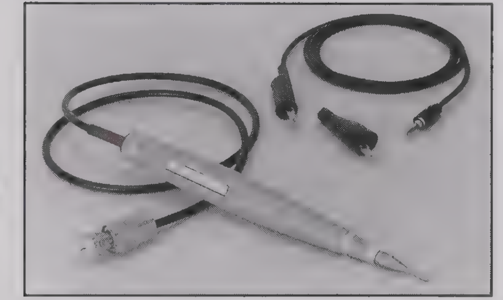


Model 5806 Kelvin Clip Lead Set: 2 clip test leads, red & black, 0.9m (36 in.) with banana plug termination. Designed to be used with Keithley instruments that measure 4-terminal resistance. A package of 8 replacement rubber bands (P/N GA-22) is available.

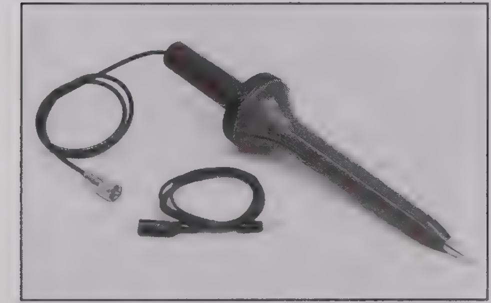
Test Leads and Probes



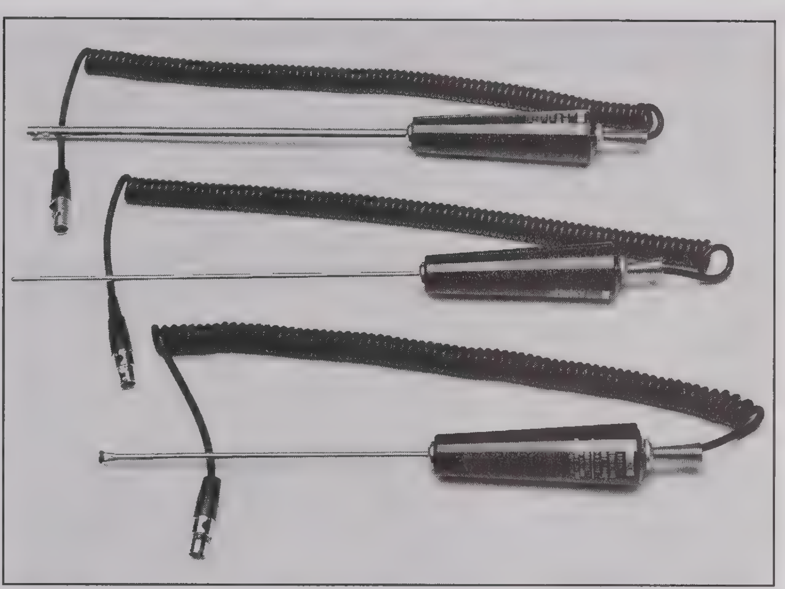
Model 5807-7 Helical Spring Point Test Leads are two excellent Kelvin test probes for Keithley instruments that measure 4-terminal resistance. The probes have pointed tips which rotate when pressure is exerted on the handle. Good contact is assured, and the handle can be held at any angle to the measurement surface. The lead wires terminate in banana jacks. Lead wire length: 2m (7 ft.).



Model 6101A Shielded Test Lead: Straight-through probe and shielded lead with 0.8m (30 in.) of shielded low noise cable terminated by Teflon-insulated UHF connector. Use with 610C or, with a 6012 adapter, with Models 602, 614, and 617.



Model 6103C Voltage Divider Probe: Permits voltage measurement to 30kV and has a 1000:1 division ratio. Accuracy is ±5% of reading. Its $3.8\times10^{11}\Omega$ input resistance permits use with Keithley electrometers and other high impedance multimeters. Connector is a UHF male plug. Requires the 6012 Triax to UHF Adapter when used with Models 602, 614, and 617. Lead length is 0.8m (30 in.).



Model 8693 General Purpose/Immersion Probe: Platinum RTD sensor. Designed for immersion in liquids as well as other general purpose applications. Measures from –220°C to +630°C; the probe has a basic tolerance of ±0.3°C at 0°C.

Probe Length: 20cm (8 in.).

Extended Cable Length: 1.5m (5 ft.).

Model 8695 Surface Probe: Platinum RTD sensor. Designed to measure the flat surfaces of solids from –50°C to +260°C; the probe has a basic tolerance of ±0.3°C at 0°C.

Probe Length: 15cm (6 in.).

Extended Cable Length: 1.5m (5 ft.).

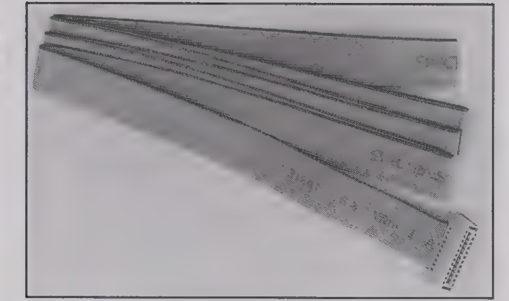
Model 8696 Air/Gas Probe: Platinum RTD sensor. Has an exposed junction within a protective shroud. Measures from –50°C to +260°C; the probe has a basic tolerance of ±0.3°C at 0°C.

Probe Length: 20cm (8 in.).

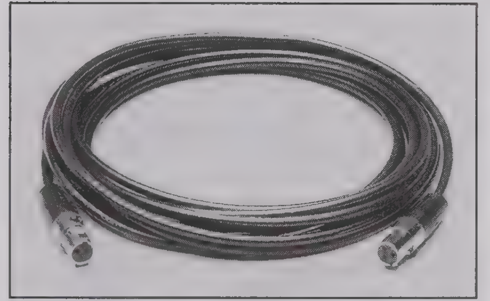
Extended Cable Length: 1.5m (5 ft.).

Cables

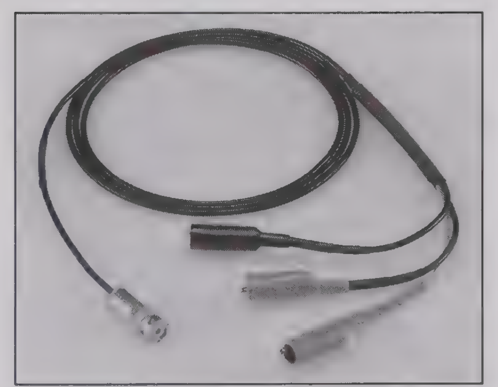
MODEL	DESCRIPTION	TYPE	TERMINATIONS From	 To	LENGTH m	 ft	USED WITH
213-RBN-2	Digital I/O	Ribbon	Card edge	Unterminated	2	6.5	213
236-ILC-3	Safety Interlock	Shielded twisted pair	3-pin round	3-pin round	3	10	236, 237, 238, 486, 487, 8006, 8007, 8008
237-ALG-2	Low Noise Input	Triax	3-slot male triax	Alligator clips (3)	2	2.4	236, 237, 238, 486, 487
1481	Low Thermal Input	Shielded twisted pair	1486 connector	Alligator clips	1.2	4	181, 182
1482	Low Thermal Input	Shielded twisted pair	1486 connector	Bare copper leads	3	10	181, 182
1506	Low Thermal Input	Triax	1486 connector	Alligator clips	1.2	4	181, 182
1507	Low Thermal Input	Triax	1486 connector	Copper spade lugs	1.2	4	181, 182
1942	External Sample Trigger	Coax	DB-25P	Male BNC, twisted pair unterm.	1.5	5	194A
3949	Interconnect Cable	Shielded	36-pin Centronics	36-pin Centronics	0.3	1	3940 Multifunction Synthesizer
4801	Low Noise Input	Coax	Male BNC	Male BNC	1.2	4	82, 480, 485, 590, 595, 7158
4802-10	Low Noise Input	Coax	Male BNC	Unterminated	3	10	82, 480, 485, 590, 595, 7158
4803	Low Noise Cable Kit	Coax	Male BNC (10)	Female BNC (5)	15.2	50	82, 480, 485, 590, 595, 7158
6011	Input	Triax	Triax connector	3 alligator clips	1.5	5	220, 224, 602, 614, 617, 617-HIQ
6011-10	Input	Triax	Triax connector	3 alligator clips	3	10	220, 224, 602, 614, 617, 617-HIQ
6427-20	Interconnect	Shielded	642 remote head	642 mainframe	6.1	20	642, 642 LNFPA
6427-50	Interconnect w/remote supply	Shielded	642 remote head	642 mainframe	15	50	642, 642 LNFPA
7007-1	Shielded IEEE-488 Interface	Shielded	Shielded IEEE-488	Shielded IEEE-488	1	3.3	IEEE-488 interconnect
7007-2	Shielded IEEE-488 Interface	Shielded	Shielded IEEE-488	Shielded IEEE-488	2	6.6	IEEE-488 interconnect
7008-3	IEEE-488 Digital	Shielded	Standard IEEE-488	Standard IEEE-488	0.9	3	IEEE-488 interconnect
7008-6	IEEE-488 Digital	Shielded	Standard IEEE-488	Standard IEEE-488	1.8	6	IEEE-488 interconnect
7024-3	Low Noise	Triax	2-slot triax	2-slot triax	0.9	3	220, 224, 263, 7058, electrometers
7024-10	Low Noise	Triax	2-slot triax	2-slot triax	3	10	220, 224, 263, 7058, electrometers
7025-10	Low Noise Input	Triax	2-slot triax	Unterminated	3	10	220, 224, 263, 7058, electrometers
7051-2	BNC Interconnect	Coax	BNC	BNC	0.6	2	590, switching external triggers
7051-5	BNC Interconnect	Coax	BNC	BNC	1.5	5	590, switching external triggers
7051-10	BNC Interconnect	Coax	BNC	BNC	3	10	590, switching external triggers
7074-MTC-20	Mass Terminated Assembly	Twisted pair (24)	75-pin connector	75-pin connector	6.1	20	7074-D, 7074-M
7075-MTC	Mass Terminated Assembly	Round ribbon	25-pin D connector	25-pin D connector	3	10	7075 bank/column, 7076 row/column
7076-CMTC	Mass Terminated Assembly	Shielded	25-pin D connector	25-pin D connector	3	10	7075 bank, 7076 column
7076-RMTC	Mass Terminated Assembly	Shielded	25-pin D connector	25-pin D connector	3	10	7075 row, 7076 row
7078-CSHP	8-Cable Set (includes 4 BNC-to-triax adapters)	Triax (4) Coax (4)	3-slot triax (4) BNC (4)	3-slot triax (4) BNC (4)	3 3	10 10	7072 to HP-4145
7078-DIN	707 Master/Slave	Twisted pair (9)	8-pin DIN	8-pin DIN	1.8	6	707
7078-MTC-5	Mass Terminated Assembly	Twisted pair (12)	38-pin connector	38-pin connector	1.5	5	7071, 7071-4, 7074-D, 7074-M
7078-MTC-20	Mass Terminated Assembly	Twisted pair (12)	38-pin connector	38-pin connector	6.1	20	7071, 7071-4, 7074-D, 7074-M
7078-TRX-3	Low Noise	Triax	3-slot triax	3-slot triax	0.9	3	236, 237, 238, 7072
7078-TRX-10	Low Noise	Triax	3-slot triax	3-slot triax	3	10	236, 237, 238, 7072
7078-TRX-20	Low Noise	Triax	3-slot triax	3-slot triax	6.1	20	236, 237, 238, 7072
7152-MTC-2	Low Noise Matrix Expansion	Triax (5)	6-pin M-series coax	6-pin M-series coax	0.6	2	7152
7152-MTC-10	Low Noise Matrix Expansion	Triax (5)	6-pin M-series coax	6-pin M-series coax	3	10	7152
7152-TRX-10	Low Noise M-Series to Triax	Triax (5)	M-series connector	3-slot triax (5)	3	10	7152, 8006
7153-TRX	Low Noise M-Series to Triax	Triax (5)	M-series connector	3-slot triax (5)	1.5	5	7153
7156-MTC-10	Mass Terminated Assembly	Ribbon	37-pin connector	37-pin connector	3	10	7156-D, 7156-M, 7156-MTR
7164-MTC-10	Mass Terminated Assembly	Ribbon	50-pin connector	50-pin connector	3	10	7164-D, 7164-M, 7164-MTR
7169-MTC-3	Mass Terminated Assembly	Twisted pair	20-pin connector	20-pin connector	3	10	7169
7401	Thermocouple Wire	Type K TC	Unterminated	Unterminated	30.5	100	740, 7402, 7057A
7754-3	BNC	Coax	BNC	Alligator clips	0.9	3	775A
8006-MJC	Red/Blk. Teflon Clip Jumpers (2)	Jumper	Pin jack	Jumper clip	0.3	1	8006
8006-MJG	Guarded Teflon Mini Jumpers (8)	Jumper	Pin jack	Pin jack	0.3	1	8006
8006-MJS-1	Red Teflon Mini Jumpers (10)	Jumper	Pin jack	Pin jack	0.3	1	8006
8006-MJS-2	Black Teflon Mini Jumpers (10)	Jumper	Pin jack	Pin jack	0.3	1	8006
8006-MJS-3	Blue Teflon Mini Jumpers (10)	Jumper	Pin jack	Pin jack	0.3	1	8006
8007-GND-3	Safety Ground Wire		Crimp lug	Crimp lug	3	10	8006, 8007
8007-MTC-3	Mass Terminated Assembly	Triax	M-series connector	3-slot triax (12)	3	10	8007 to 7072
8008-BAN	1 Red/1 Black Cables	Single wire (2)	Safety banana	Safety banana	0.25	0.8	487, 8008
19072	Input	Coax	UHF connector	Alligator clips	0.9	3	610C Electrometer
32418	Interconnect	Coax	UHF connector	MHV connector	0.9	3	247 Power Supply
CA-18-1	Shielded	Coax	Dual banana plug	Dual banana plug	1.2	4	Binding post inputs
SC-9	Low Noise	Coax	Unterminated	Unterminated	Custom		
SC-22	Low Noise	Triax	Unterminated	Unterminated	Custom		



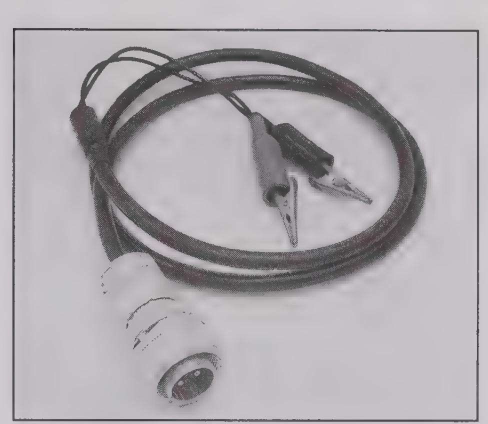
213-RBN-2 Digital I/O Cable: 2m (6½ ft.) of ribbon cable terminated on one end with card edge connector. For use with Model 213 Quad Voltage Source.



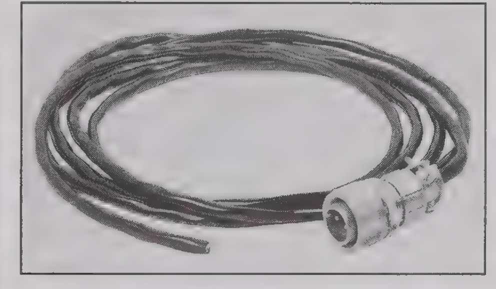
236-ILC-3 Safety Interlock Cable: Designed to connect the lid interlock circuit of the Model 8006, 8007 and 8008 test fixtures to the interlock circuit of the Models 236, 237 and 238 SMUs and 486 and 487 Picoammeters..



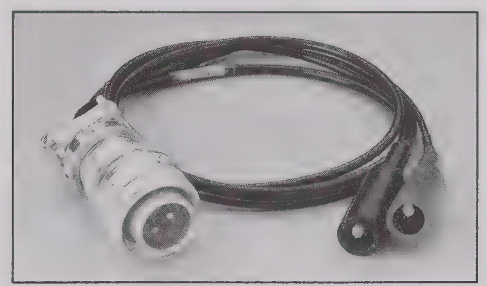
237-ALG-2: 2m (2.4 ft.) of low noise triax cable (SC-22) terminated with a 3-slot male triax connector on one end and 3 alligator clips on the other. For use with Models 236, 237, 238, 486, and 487.



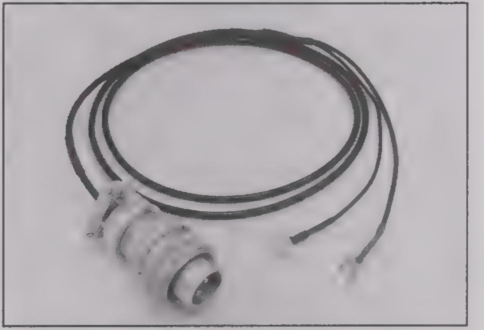
Model 1481 Low Thermal Input Cable: 1.2m (4 ft.) of shielded twisted pair cable terminated on one end with Model 1486 (mating connector to Models 181 and 182) and two copper alligator clips on the other. Useful for making temporary connections in low voltage circuits, especially in the presence of a magnetic field.



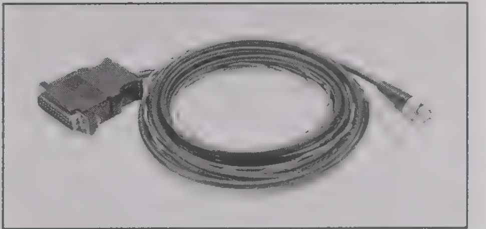
Model 1482 Low Thermal Input Cable: Similar to Model 1481; 3m (10 ft.) of shielded twisted pair cable terminated with a 1486 connector and bare copper leads, allowing special low thermal input connections to Models 181 and 182.



Model 1506 Low Thermal Input Cable: 1.2m (4 ft.) triax cable with a Model 1486 connector on one end and two copper alligator clips on the other.



Model 1507 Low Thermal Input Cable: 1.2m (4 ft.) triax cable with a Model 1486 connector on one end and two copper spade lugs on the other.



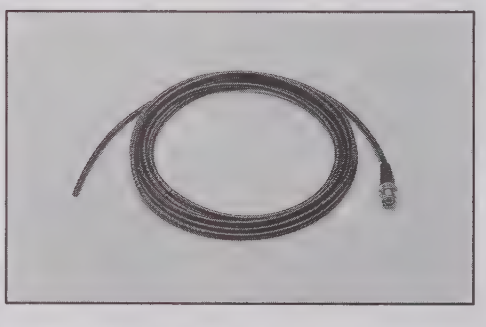
Model 1942 External Sample Trigger Cable: Enables external control of the Model 194A sample rate. DB-25P connector with 1.5m (5 ft.) of RG-58 coax cable terminated in a male BNC connector and 1.5m (5 ft.) of twisted pair unterminated 26 gauge wire.

Cables

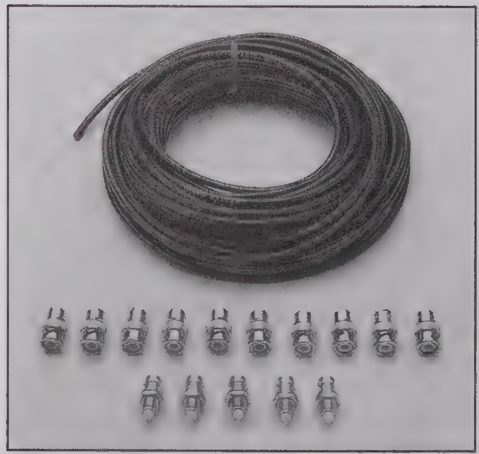
Model 3949 Interconnect Cable: For synchronous operation of multiple Model 3940 Multifunction Synthesizers.

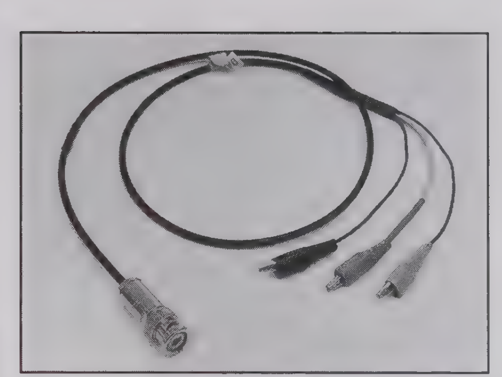
Model 4801 Input Cable: Low noise coax cable, 1.2m (48 in.) in length, with male BNC connectors on each end. For use with Models 480, 485 and 7158.

Model 4802-10: 3m (10 ft.) of low noise coax cable with male BNC connector at one end and unterminated at the other.



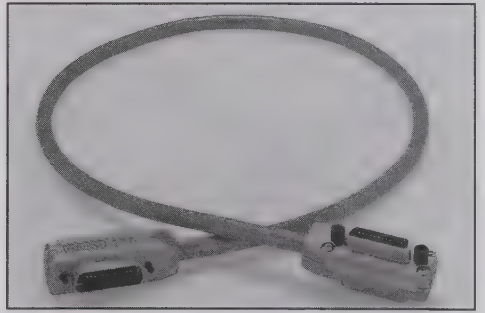
Model 4803 Low Noise Cable Kit: Includes 15m (50 ft.) of low noise coax cable, 10 male BNC connectors, and 5 female BNC chassis-mount connectors.





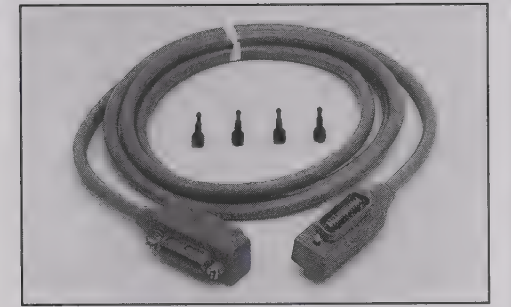
Model 6011: 1.5m (5 ft.) of triax cable (SC-22) terminated with a 2-lug triax plug on one end and 3 alligator clips on the other. For use with Models 220, 224, 602, 614, 617 and 617-HIQ. Also available in 3m (10 ft.) length (**Model 6011-10**).

Model 6427-20: 6m (20 ft.) remote head to mainframe interconnect cable for Model 642. Also available in 15m (50 ft.) length with remote power supply (**Model 6427-50**).

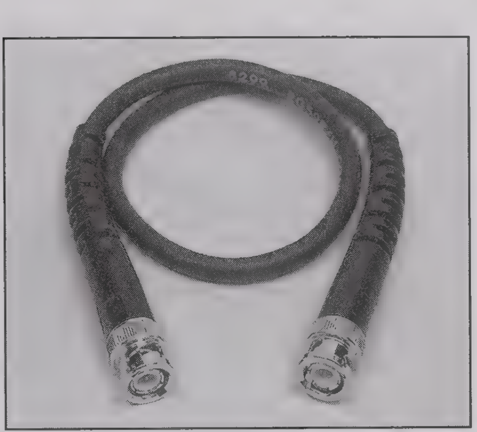


Model 7007-1: 1m (3.3 ft.) shielded IEEE-488 interface cable with shielded connector on each end (metric). Also available in 2m (6.6 ft.) length (**Model 7007-2**).

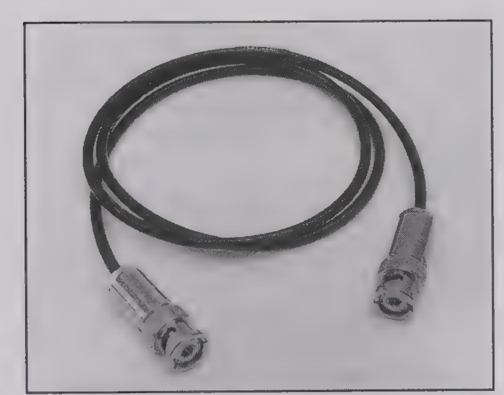
Cables



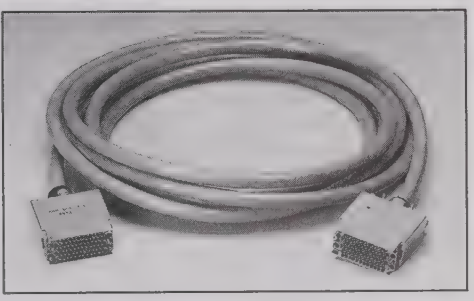
Model 7008-3: 0.9m (3 ft.) IEEE-488 digital cable terminated with an IEEE-488 connector on each end, with metric mating screws. Also available in 1.8m (6 ft.) length **(Model 7008-6).**



Model 7051-2: 0.6m (2 ft.) BNC to BNC cable (RG-58C). Also available in 1.5m (5 ft.) and 3.0m (10 ft.) lengths **(Models 7051-5 and 7051-10).**

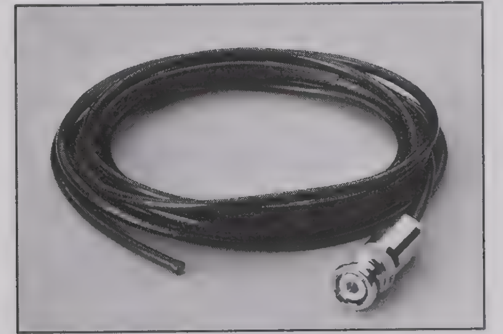


Model 7024-3: 0.9m (3 ft.) low noise triax cable (SC-22) with 2-lug male triax connectors on each end. Also available in 3.0m (10 ft.) length (**Model 7024-10**).

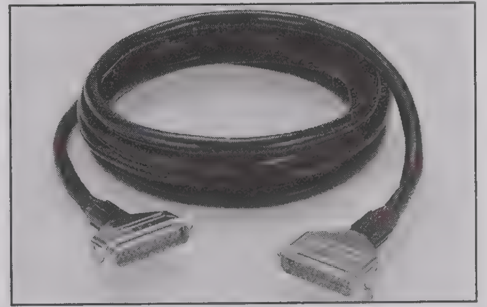


Model 7074-MTC-20: 6m (20 ft.) mass terminated cable assembly for connection to channel inputs on the 7074 multiplexer switching card. The cable has 24 sets of shielded twisted pair wires for isolation of critical circuits and noise rejection in the system. The cable is terminated at each end in a 75-pin connector block with strain relief.

Model 7074-MTC-20 can be used as is or cut in half to make two 10 ft. cables for termination in unique device-under-test fixtures and interfaces.



Model 7025-10: 3m (10 ft.) low noise triax input cable (SC-22) terminated on one end with 2-lug male triax connector.

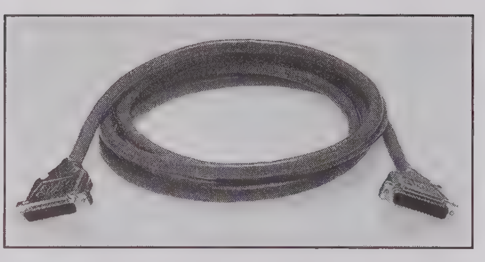


Model 7075-MTC: 3m (10 ft.) cable assembly with mass terminated connector on each end. For use as row or column connections on the 7076, and for bank or column connections on the 7075. The number of cable assemblies required depends on how the 7075 or 7076 is configured.

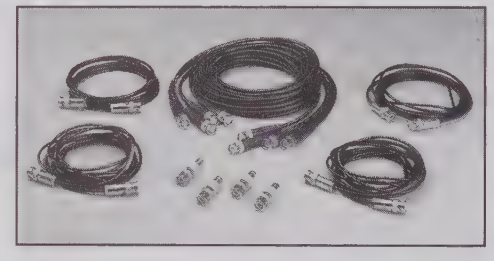
Model 7076-RMTC: High isolation 3m (10 ft.) cable assembly with mass terminated connector on each end. For use as row connections on the 7075 and 7076. A separate guard shields each HI signal path. The number of cable assemblies required depends on how the 7075 or 7076 is configured.

Cables

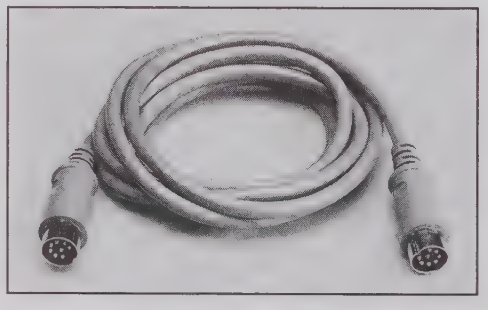
Model 7076-CMTC: High isolation 3m (10 ft.) cable assembly with mass terminated connector on each end. For bank connections on the 7075 or column connections on the 7076. A separate guard shields each HI signal path. The number of cables required depends on how the 7075 or 7076 is configured.

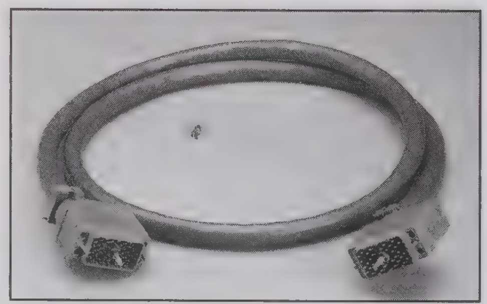


Model 7078-CSHP is a set of eight 3m (10 ft.) cables and four BNC-to-triax adapters for connecting between the Model 7072 8x12 Semiconductor Matrix Card and an HP-4145 Semiconductor Parameter Analyzer. Four 3-slot triax cables connect to Source/Measurement Unit outputs. Four BNC to BNC coax cables adapt the measurement and source modules in the HP-4145 to the connectors of 7072.



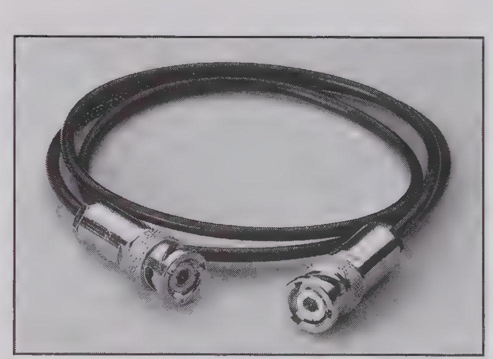
Model 7078-DIN: This 1.8m (6 ft.) cable accessory connects between Model 707 mainframes when operated as one unit in Master/Slave mode. One cable is required for each mainframe.



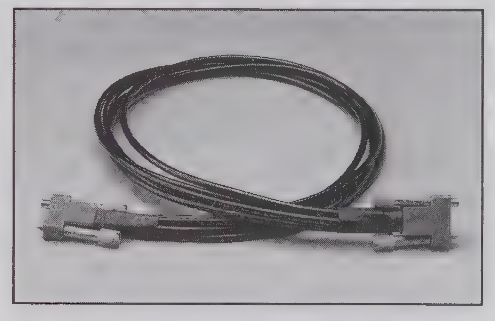


Model 7078-MTC-5: 1.5m (5 ft.) mass terminated cable assembly for connection to column inputs on the 7071 and 7071-4 Matrix Switch Cards. The cable is also used for matrix expansion by connecting row inputs between main- frames when using 7071, 7071-4, or 7074 switch cards. The cable has 12 sets of shielded twisted pair wires for isolation of critical circuits and noise rejection in the system. The cable is terminated at each end in a 38-pin connector block with strain relief.

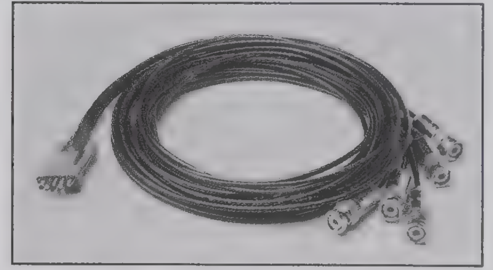
Model 7078-MTC-20 can be used as is or cut in half to make two 10 ft. cables for termination in unique device under test fixtures and interfaces.



Model 7078-TRX-3: 0.9m (3 ft.) low noise triax cable terminated at both ends in 3-slot triax connectors. Also available in 3m (10 ft.) and 6m (20 ft.) lengths (**Models 7078-TRX-10** and **7078-TRX-20**).

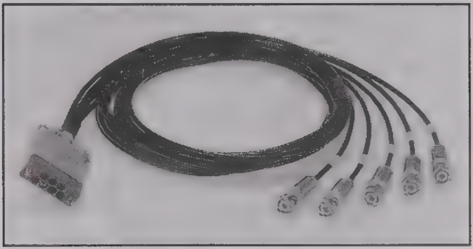


Model 7152-MTC-2: Set of five 0.6m (2 ft.) low noise triax cables terminated at each end in a 6-position M-series coax connector block. This cable provides quick connection between 7152 Low Current Matrix cards for easy expansion, and is compatible with Model 7152-MTR bulkhead mount mating connector. Also available in 3m (10 ft.) length (**Model 7152-MTC-10**) for connection between the matrix and the device under test.

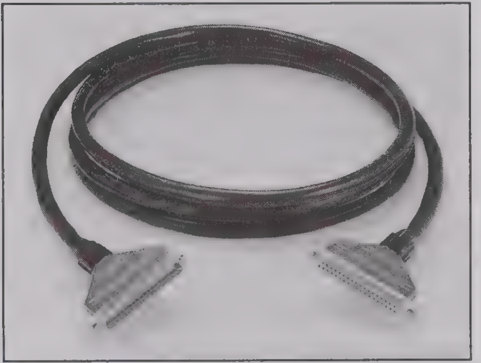


Model 7152-TRX-10: Set of five 3m (10 ft.) low noise triax cables terminated at one end in a single M-series connector block and at the other end in 3-slot triax connectors. This cable is most useful for direct connection to electrometers and Source/Measure Units.

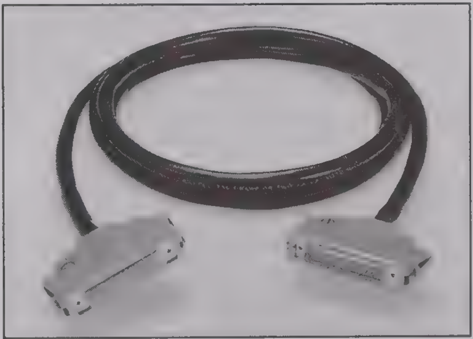
Cables



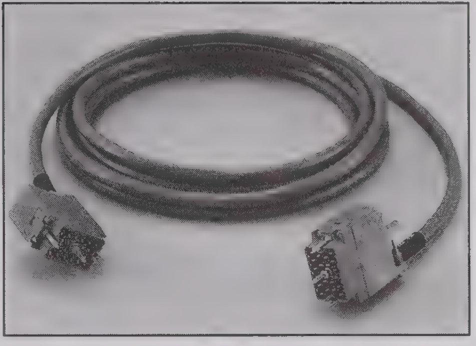
Model 7153-TRX: 1.5m (5 ft.) low noise cable assembly with M-series connector at one end for row or column connections to the 7153, and five 3-slot male triax connectors at the other end. Two 7153-TRX cable assemblies are required to make all connections to the 7153 card.



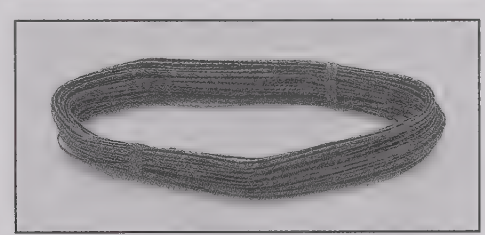
Model 7156-MTC-10: 3m (10 ft.) 37-conductor ribbon cable assembly terminated at both ends with a 37-pin connector block. This cable is compatible with 7156 scanner cards and 7156-MTR bulkhead mounting mating connector.



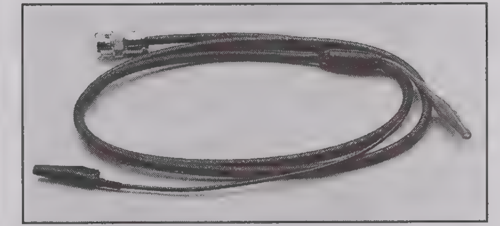
Model 7164-MTC-10: 3m (10 ft.) 50-conductor ribbon cable assembly terminated at both ends in a 50-pin connector block. This cable is compatible with 7164 scanner cards and 7164-MTR bulkhead mount mating connector.



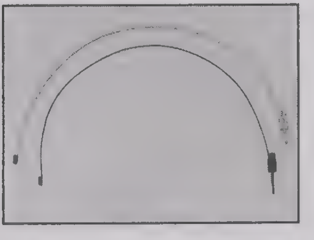
Model 7169-MTC-3: 3m (10 ft.) twisted pair cable assembly terminated at both ends in a 20-pin connector block. This cable is compatible with the Model 7169 20 Form C Switching Card and 7169-MTR bulkhead mount mating connector.



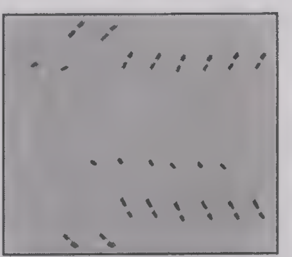
Model 7401: Type K thermocouple wire kit includes 30.5m (100 ft.) of type K (chromel-alumel) thermocouple wire.



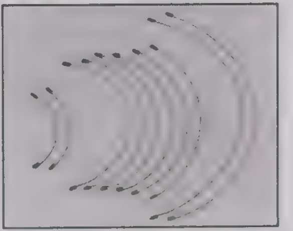
Model 7754-3 BNC to Alligator Cable: 0.9m (3 ft.) terminated on one end with a BNC plug and on the other with two alligator clips.



Model 8006-MJC: Red and black pair of Teflon clip jumpers. For use with Model 8006 Component Test Fixture.



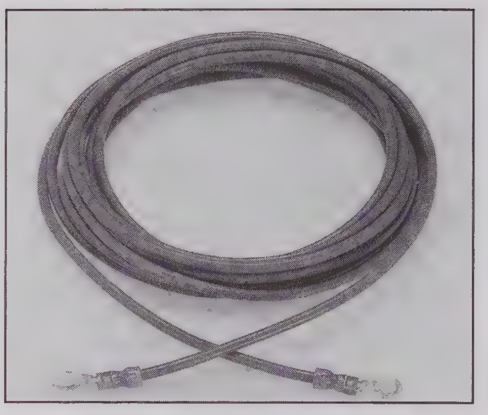
Model 8006-MJG: Eight guarded Teflon mini jumpers. For use with Model 8006 Component Test Fixture.



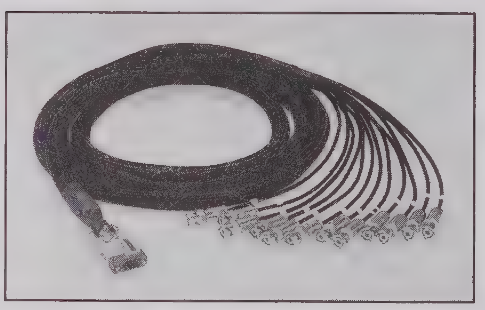
Model 8006-MJS: Set of 10 Teflon mini jumpers. Available in red (**Model 8006-MJS-1**), black (**Model 8006-MJS-2**), and blue (**Model 8006-MJS-3**). For use with Model 8006 Component Test Fixture.

Cables

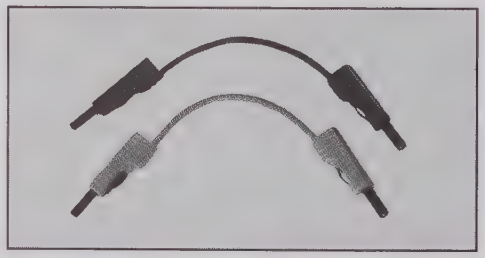
Model 8007-GND-3: Safety ground wire. For use with Model 8007 Semiconductor Test Fixture and Model 8006 Component Test Fixture.



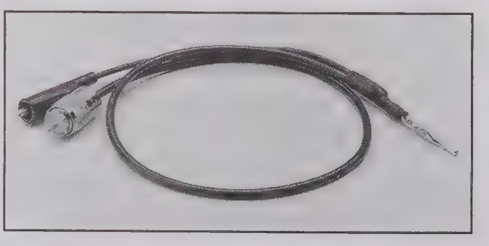
Model 8007-MTC-3: Mass terminated cable assembly, 3m (10 ft.). For use with Model 8007 Semiconductor Test Fixture.



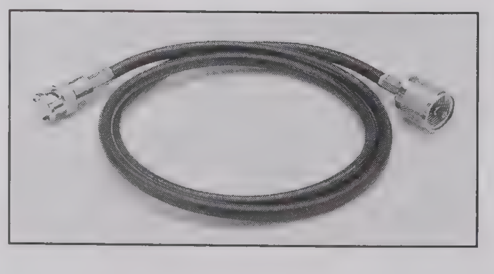
Model 8008-BAN: Consists of one red and one black cable terminated with male safety banana plugs. Used to interface the 8008 Test Fixture to the 487 Picoammeter/Source.

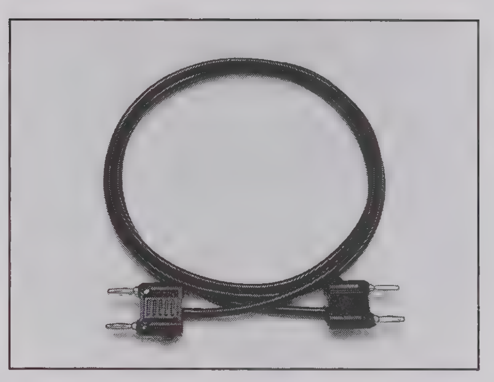


19072 Input Cable: 0.9m (3 ft.) of coax cable (SC-9) with UHF connector on one end and alligator clips on the other. For use with Model 610C.

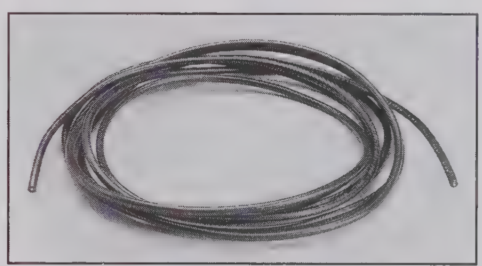


32418: UHF-MHV cable supplied with Model 6105 for connection to Model 247. Cable length 0.9m (3 ft.).

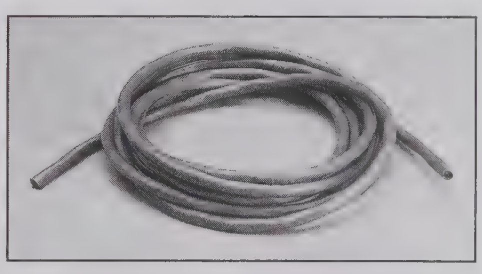




CA-18-1: 1.2m (4 ft.) shielded cable terminated with a dual banana plug on each end. For use with binding post inputs.



SC-9: Low noise coax cable without connectors (sold by the foot).

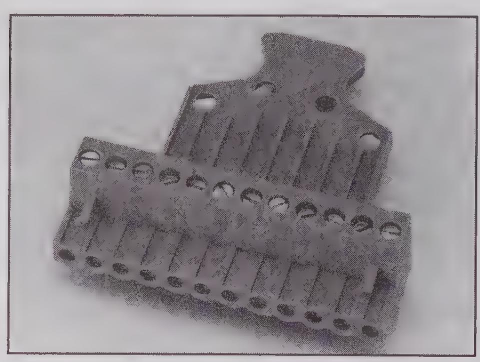


SC-22: Low noise triax cable without connectors (sold by the foot).

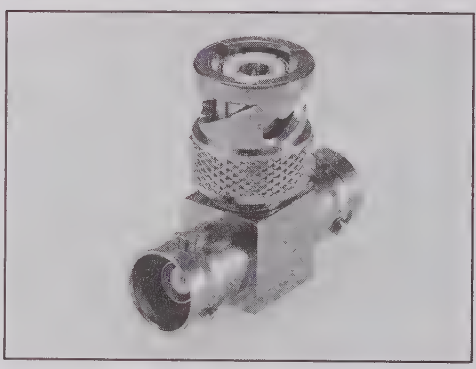
Connectors and Adapters

MODEL	NAME	USE WITH
213-CON	Analog Output Connector	213
237-TRX-T	3-Slot Male to Dual 3-Lug Female Triax Tee Adapter	7072, 7072-HV, 7078-TRX cables
237-TRX-TBC	3-Lug Female Triax Bulkhead Connector	7072, 7072-HV, 7078-TRX cables
1483	Low Thermal Connection Kit	181, 182
1484	Refill Kit for 1483 Kit	181, 182
1485	Female Low Thermal Input Connector	181, 182
1486	Male Low Thermal Input Connector	181, 182
1488	Low Thermal Shorting Plug	181, 182
1951	Platinum RTD Adapter	195A
1993	Quick Disconnect Scanner Connector Kit	199/1992
2286	Safety Output Assembly	228A
4804	Male BNC to 2-Lug Female Triax Adapter	480, 485
4851	BNC Shorting Plug	480, 485, 230-1
5904	20nF/20mS Adapter (not calibrated to mainframe)	590
5951	Remote Input Coupler for Model 82	Model 82
6012	Triax to UHF Adapter	220, 224, 602, 614, 617
6146	2-Lug Triax Tee Adapter	602, 614, 617
6147	2-Slot Male Triax to Female BNC Adapter	220, 224, 602, 614, 617
6167	Guarded Input Adapter for 220, 224, 602, 614	220, 224, 614
6171	3-Slot Male to 2-Lug Female Triax Adapter	6011, 7024
6172	2-Slot Male to 3-Lug Female Triax Adapter	220, 224, 602, 614, 617
6176	Adapter Kit: Includes Models 6146, 6147, 6171, 6172, 7078-TRX-BNC, 4804	220, 224, 602, 614, 617
6424	BNC Input Adapter	642
6425	GenRad GR874® Air Line Input Adapter	642
7010	Shielded IEEE-488 to IEEE-488 Adapter	IEEE-488 Interconnect
7023	2-Lug Female Triax Bulkhead Connector	6011, 7024
7074-CIT	Contact Extraction Tool	7074-KIT, 7074-MTR
7074-HCT	Hand Crimping Tool	7074-KIT, 7074-MTR
7074-KIT	75-Pin Mass Terminated Plug w/Contacts	7074-D, 7074-M, 7074-MTR
7074-MTR	75-Pin Mass Terminated Receptacle w/Contacts	7074-D, 7074-M, 7074-KIT, 7074-MTC
7074-RTC	Relay Test Shorting Connector	7074-D, 7074-M
7078-CIT	Contact Insertion/Extraction Tool	7078-KIT, 7078-MTR, 7152-KIT, 7152-MTR, 7169-KIT, 7169-MTR
7078-HCT	Hand Crimping Tool for 7078-KIT, 7169-KIT	7078-KIT, 7169-KIT
7078-KIT	Connector Kit	7071, 7071-4, 7074-D, 7074-M, 7078-MTR
7078-MTR	Mass Terminated Receptacle, Bulkhead Mount	7078-KIT, 7078-MTC
7078-TRX-BNC	3-Lug Triax to BNC Adapter	486, 487, 4801, 7051, 7072, 7072-HV
7078-TRX-GND	3-Lug Triax to BNC Adapter (guard removed)	236, 237, 238, 4801, 7051, 7072, 7072-HV
7078-TRX-T	3-Lug Triax Tee Adapter	7072, 7072-HV, 7078-TRX cables
7078-TRX-TBC	3-Lug Female Triax Bulkhead Connector w/Cap	7078-TRX cables
7152-HCT	Hand Crimp Tool for 7152-KIT, 7152-MTR	7152-KIT, 7152-MTR
7152-KIT	6-Position M-Series Plug w/Contacts	7152, 7152-MTR
7152-MTR	6-Position M-Series Receptacle w/Sockets	7152, 7152-KIT, 7152-MTC-2, 7152-MTC-10
7156-KIT	37-Pin Mass Terminated Connector	7156-D, 7156-M
7156-MTR	Mass Terminated Bulkhead Mount Receptacle	7156-D, 7156-M, 7156-MTC-10
7164-KIT	50-Pin Mass Terminated Connector	7164-D, 7164-M, 7164-MTR
7164-MTR	50-Pin Mass Terminated Bulkhead Mount Receptacle	7164-D, 7164-M, 7164-MTC-10
7169-KIT	20-Pin Mass Terminated Connector	7169
7169-MTR	Mass Terminated Bulkhead Mount Receptacle	7169, 7169-MTC-3
7755	50Ω Feed-Through Terminator	RG 58 Cable
8691	Pt RTD Connector Adapter Kit	195A
CS-115	UHF-BNC Adapter	610C
CS-141	2-Lug Male Triax Cable Mount Connector	SC-22 Cable
CS-631	3-Lug Male Triax Cable Mount connector	SC-22 Cable

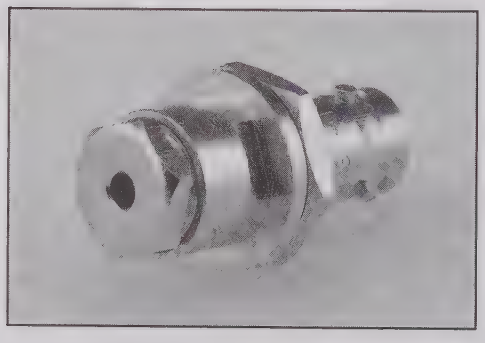
Connectors and Adapters



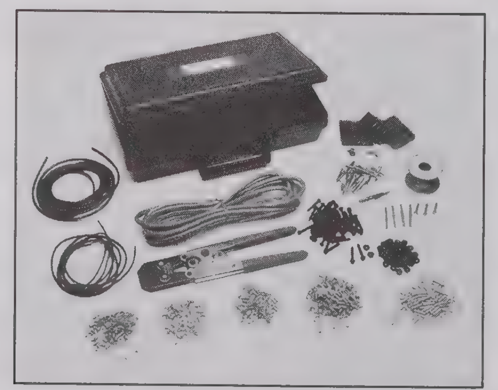
Model 213-CON Analog Output Connector: Quick disconnect analog output connector for Model 213 Quad Voltage Source. Screw terminals provided for connection of test leads.



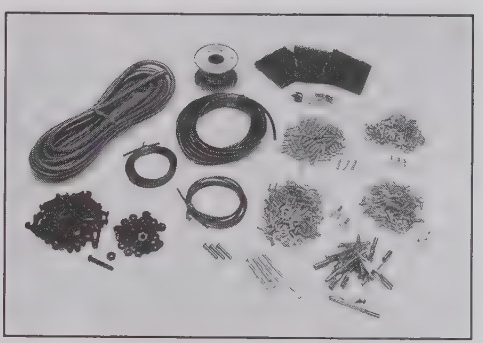
Model 237-TRX-T: 3-slot male to dual 3-lug female triax tee adapter for use with 7078-TRX cables and 7072/7072-HV Semiconductor Matrix Cards.



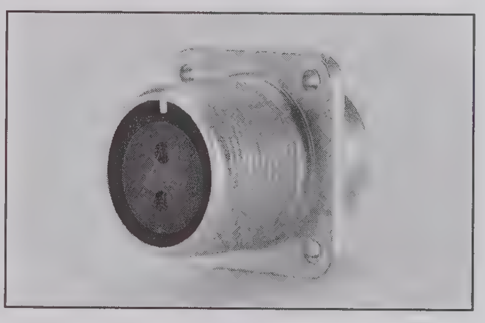
Model 237-TRX-TBC: 3-lug female triax bulkhead connector with cap for assembly of custom panels and interface connections.



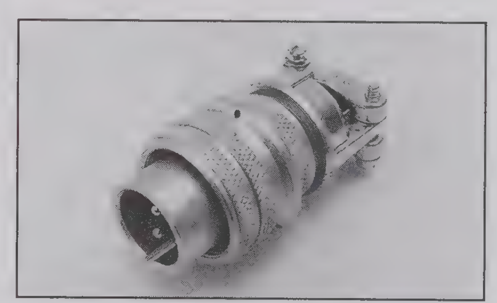
Model 1483 Low Thermal Connection Kit: Contains crimp tool, pure copper lugs, alligator clips, and assorted hardware.



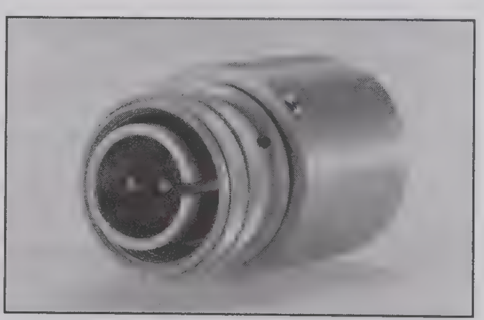
Model 1484 Refill Kit: Replacement parts for 1483 kit, including lugs, clips, and hardware.



Model 1485 Female Low Thermal Input Connector: For Models 148, 181 and 182.



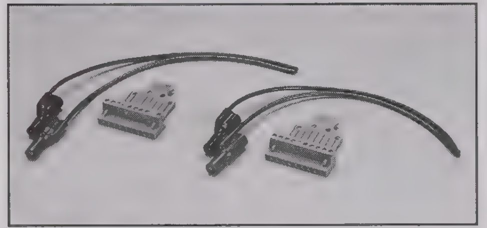
Model 1486 Male Low Thermal Connector: Mates with the input connector for Models 148, 181 and 182. Allows the user to make a custom input cable.



Model 1488 Low Thermal Shorting Plug: For checking proper operation and for calibrating Models 148, 181 and 182. Special construction minimizes errors caused by thermal EMF.

Connectors and Adapters

Model 1951 Input Adapter Box: Provides a means of interfacing RTD thermometer probes terminated with a 4-wire instrumentation connector to the banana jacks on the Model 195A.

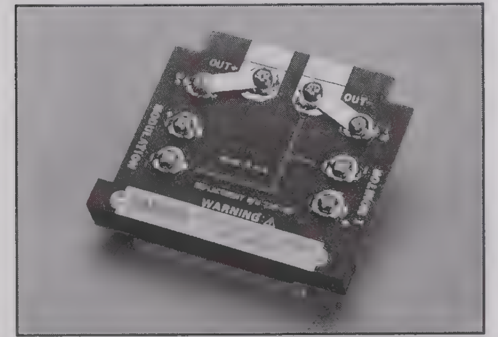


Model 1993 Quick Disconnect Scanner Connector Kit: Input connector and output lead set for Model 1992 8-Channel Scanner. Consists of two 10-contact quick disconnect connectors, 2 sets of test leads (red and black), and 10 tie wraps.

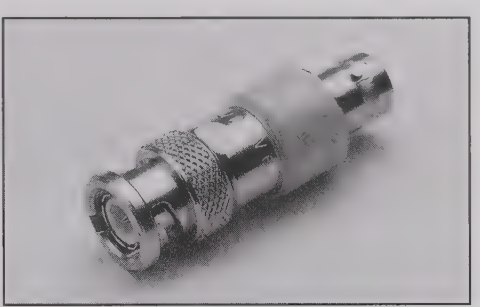
Maximum Connector Wire Size: 14 AWG

Test Lead Terminations: Fixed sheath stacking banana plug on one end, unterminated on the other end.

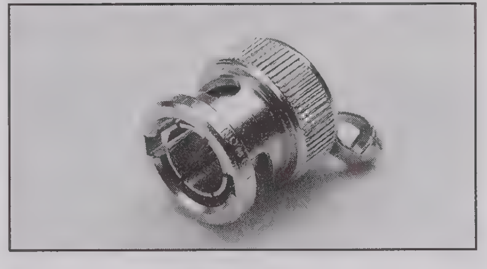
Test Lead Length: 22.9cm (9 in.).



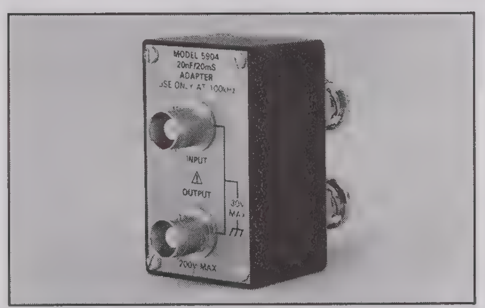
Model 2286 Safety Output Connector slides into Model 228 or 228A Current/Voltage Source to assure that the active outputs are not accessible. Outputs are disconnected when the safety card is removed from the instrument. The connector provides screw terminals for Force and Sense on both High and Low outputs as well as separate Current Monitor and Modulation Input connections.



Model 4804: 2-slot male BNC to 2-lug female triax adapter. Used to adapt triax cables to 2-lug BNC input connectors.

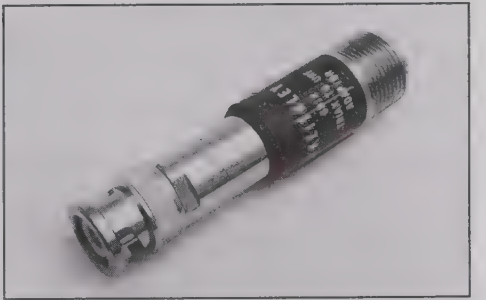


Model 4851: BNC shorting plug.



Model 5904: 20nF/20mS adapter. Extends range of Model 590/100k.

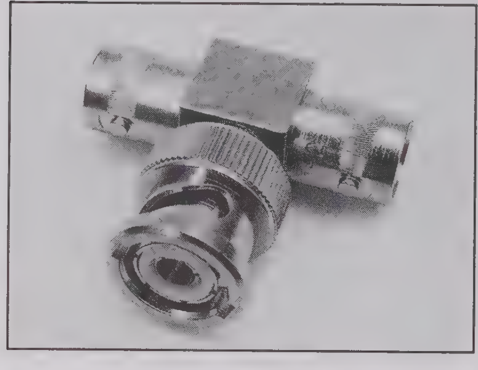
Model 5951 Remote Input Coupler: for Model 82. Includes the remote input coupler, five 1.2m low noise BNC cables (Model 4801), two 1m IEEE-488 cables (Model 7007-1), one 2m shielded IEEE-488 cable (Model 7007-2), and three 0.6m RG-58C BNC-to-BNC cables (Model 7051-2).



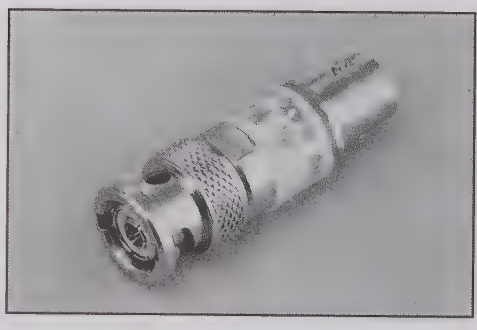
Model 6012 2-Slot Triax to UHF Adapter: Permits using Models 220, 224, 602, 614, 617, and 619 with all Keithley electrometer accessories having UHF type connectors.

Connectors and Adapters

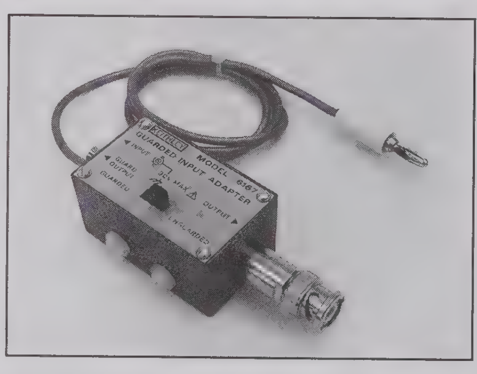
Model 6146 2-Slot Triax Tee Adapter: To connect multiple inputs to Models 602, 614, 617, and 619; allows easy connection of external feedback elements.



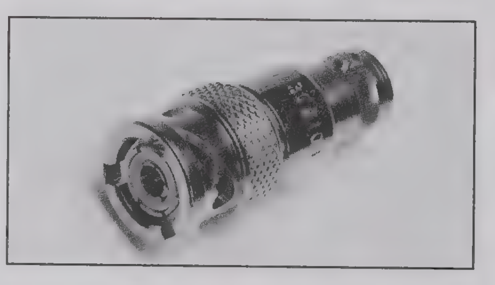
Model 6147 2-Slot Triax to BNC Adapter: Permits using Models 220, 224, 602, 614, and 617 with accessories having BNC connectors.



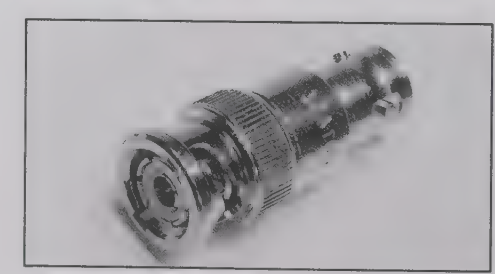
Model 6167 Guarded Input Adapter: Reduces effective cable capacity by driving the inner shield of the triax cable at Guard potential. For use with Models 220, 224, and 614. 2-slot triax female to 2-slot triax male.

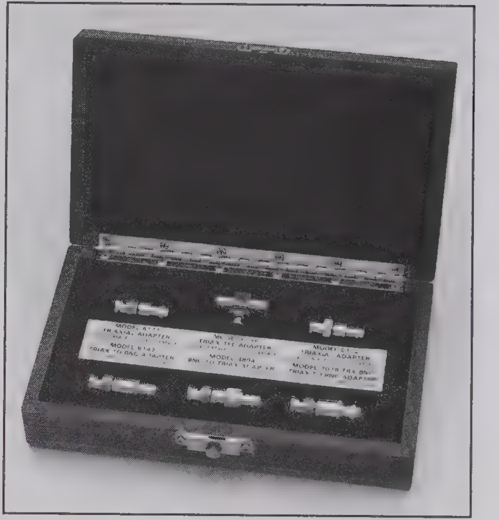


Model 6171: 3-slot male to 2-lug female triax adapter. Adapts 7024 and 6011 cables to 3-lug triax input connectors.

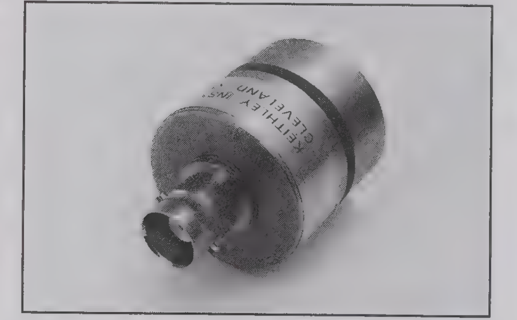


Model 6172: 2-slot male to 3-lug female triax adapter. For use in adapting Models 220, 224, 602, 614, 617, and 619 inputs to 3-lug triax cables.

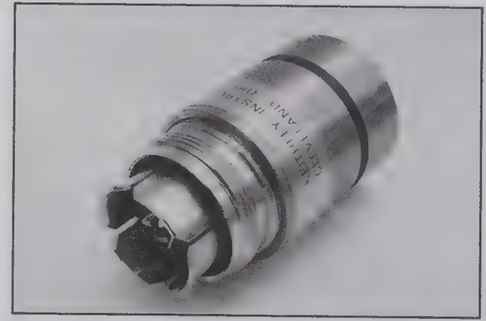




Model 6176 Adapter Kit: Consists of 6146, 6147, 6171, 6172, 7078-TRX-BNC, and 4804 in a compartmentalized box. Use when interfacing BNC, 2-lug triax, and/or 3-lug triax instrumentation.

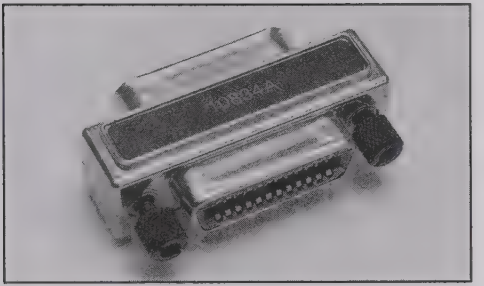


Model 6424: BNC adapter for use with Model 642. It is the most convenient connection method, limited by currents generated in the flexible cabling.

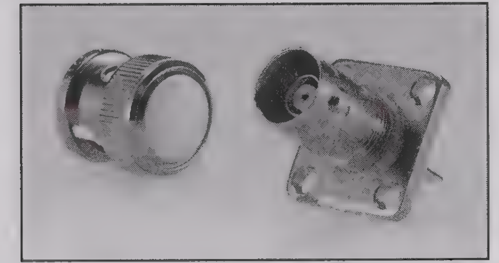


Model 6425: Converts the input of Model 642 to a GR874® rigid air line connection, permitting decades of improvement in current resolution over Model 6424.

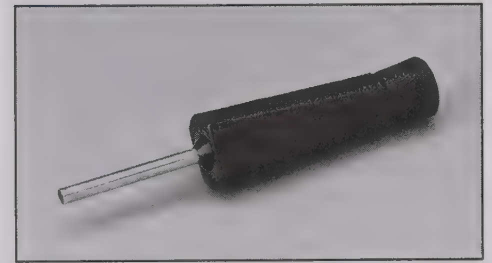
Connectors and Adapters



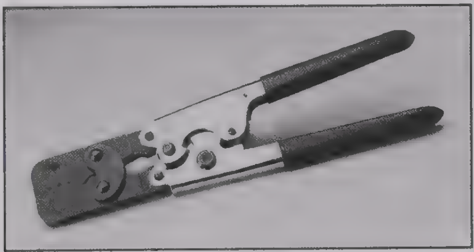
Model 7010 Shielded IEEE to IEEE Adapter: Provides additional clearance between IEEE-488 cable and rear panel, allowing easier access to switches, cables, and other connectors.



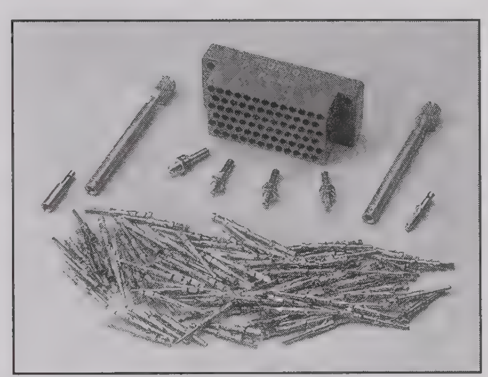
Model 7023 2-Lug Triax Bulkhead Mount Connector: Chassis mount connector mates with Keithley accessory cables 6011 and 7024 series.



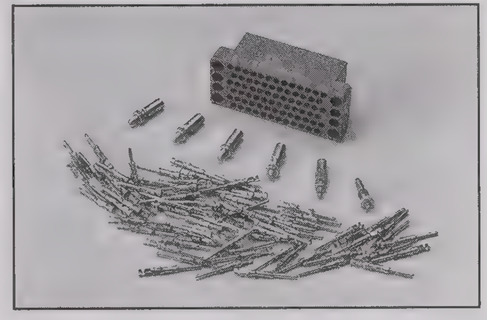
Model 7074-CIT: Contact extraction tool for removal of contacts from 7074-MTC cables and connectors.



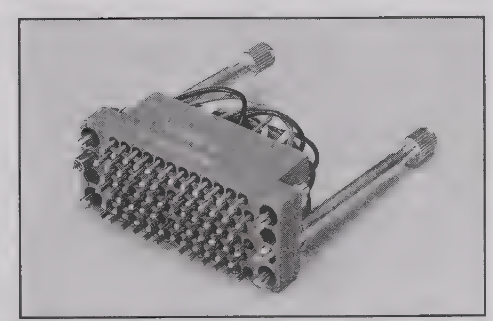
Model 7074-HCT: Contact crimping pliers for assembly of cables and connectors using 7074-MTR or 7074-KIT.



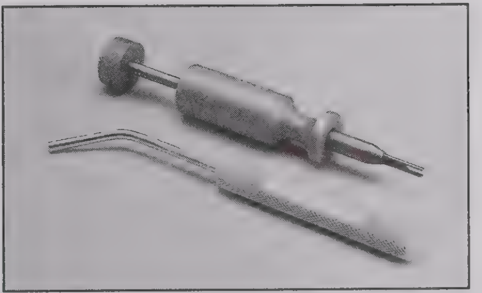
Model 7074-KIT: 75-pin plug assembly with strain relief and 80 contacts for assembly of custom cable and harnesses compatible with 7074 multiplexer card and 7074-MTR mass terminated receptacle.



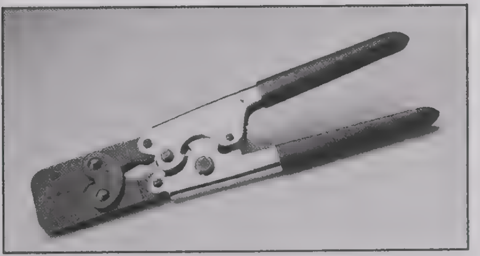
Model 7074-MTR: 75-pin bulkhead mount receptacle with 80 contacts for custom interface and patch panels compatible with 7074-MTC and 7074-KIT.



Model 7074-RTC: Relay test connector for 7074-D and 7074-M. The 7074-RTC adapts column inputs with jumper interconnects necessary when running relay test software supplied with the 707 mainframe.



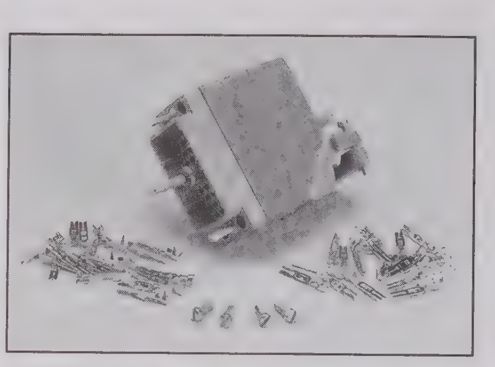
Model 7078-CIT: Contact insertion and extraction tool for assembly and maintenance of 7078-MTC cables and connectors.



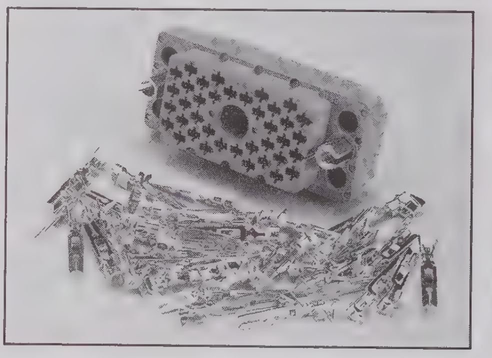
Model 7078-HCT: Contact crimping pliers for assembly of cables and connectors using 7078-MTR or 7078-KIT.

Connectors and Adapters

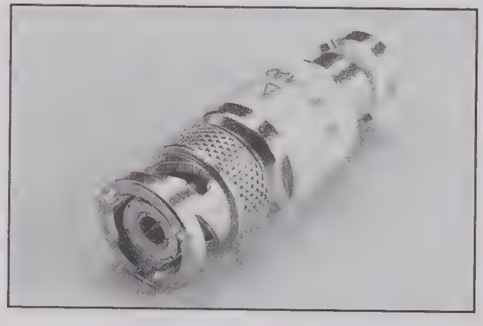
Model 7078-KIT: 38-pin plug assembly with strain relief and 40 contacts for assembly of custom cable and harnesses compatible with Model 7071 8×12 Matrix Card, Model 7071-4 Dual 4×12 Matrix Card, Model 7074 Eight 1×12 Multiplexer Card, and 7078-MTR Mass Terminated Receptacle.



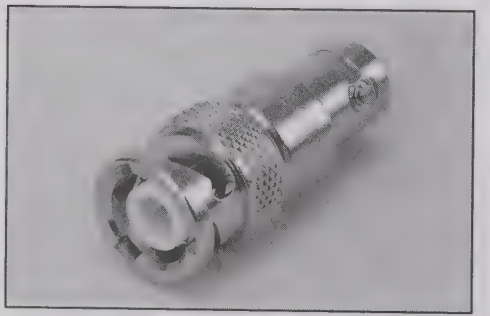
Model 7078-MTR: 38-pin bulkhead mount receptacle with 40 contacts for custom interface and patch panels compatible with 7078-MTC and 7078-KIT.

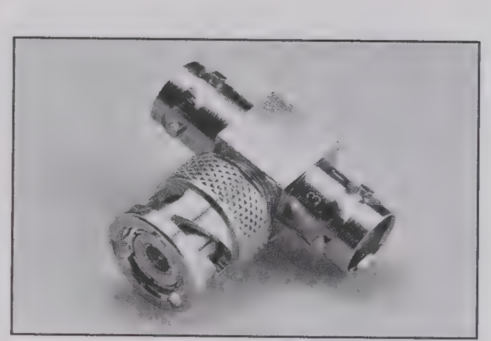


Model 7078-TRX-BNC: 3-slot male triax to BNC adapter for use with 7072 Semiconductor Matrix Card and 7051 and 4801 cables.

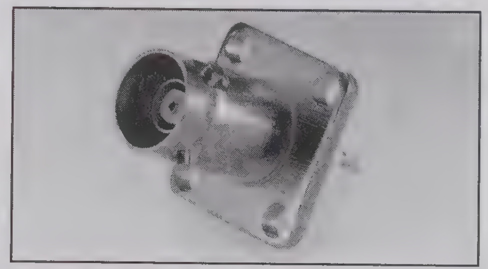


Model 7078-TRX-GND: 3-lug triax to BNC adapter (guard removed) for adapting non-guarded measurements to 236, 237 or 238 SMUs, 7072 or 7072-HV Semiconductor Matrix Cards, or 8006 or 8008 Test Fixtures.

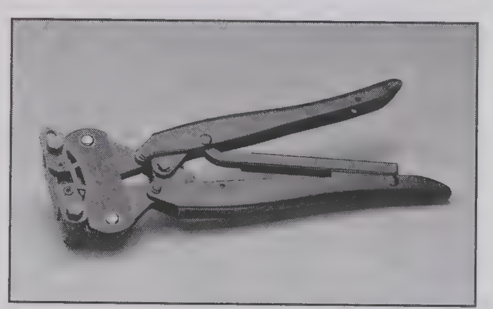




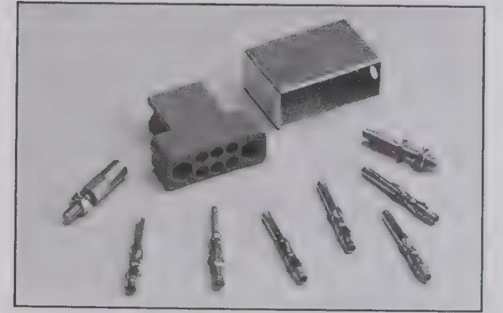
Model 7078-TRX-T: 3-slot male to dual 3-lug female triax tee adapter for use with 7078-TRX cables and 7072 Semiconductor Matrix Cards.



Model 7078-TRX-TBC: 3-lug female triax bulkhead connector with cap for assembly of custom panels and interface connections.

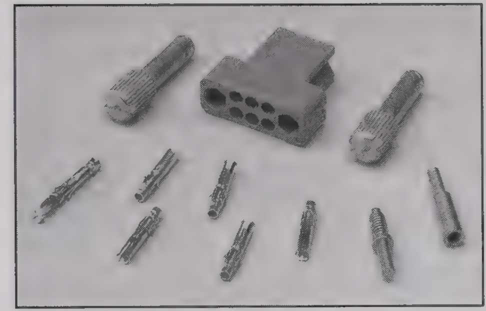


Model 7152-HCT: Contact crimping pliers for assembly of cables and connectors using 7152-MTR or 7152-KIT.

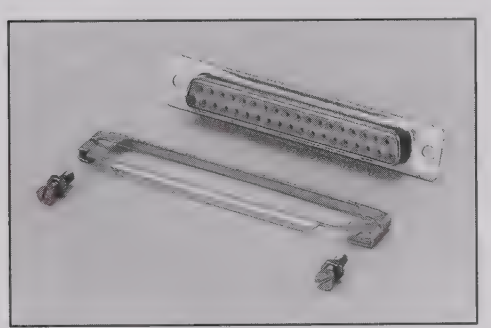


Model 7152-KIT: 6-pin plug assembly with strain relief and contacts for assembly of custom cable and harnesses compatible with Model 7152 4×5 Low Current Matrix Card and 7152-MTR Mass Terminated Receptacle.

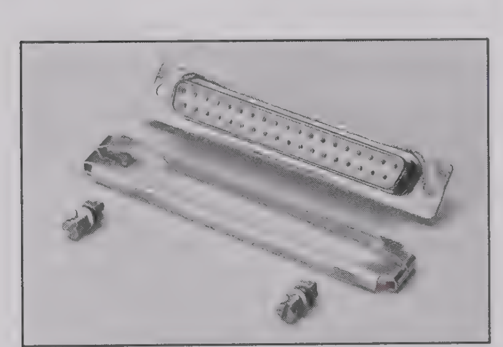
Connectors and Adapters



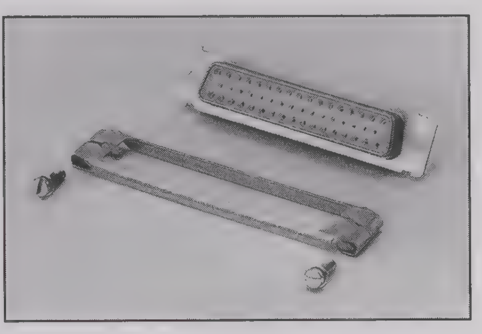
Model 7152-MTR: 6-pin bulkhead mount receptacle with contacts for custom interface and patch panels compatible with 7152-MTC and 7152-KIT.



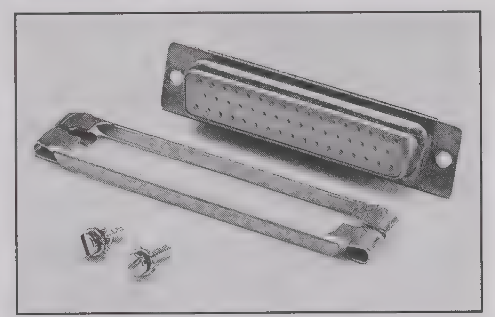
Model 7156-KIT: 37-pin D-Sub connector for assembly of custom cables and harnesses compatible with Models 7156-D and 7156-M General Purpose Multiplex Cards.



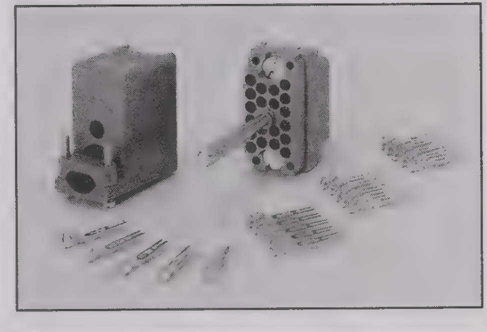
Model 7156-MTR: 37-pin mass terminated receptacle for custom interface and patch panels compatible with 7156-MTC.



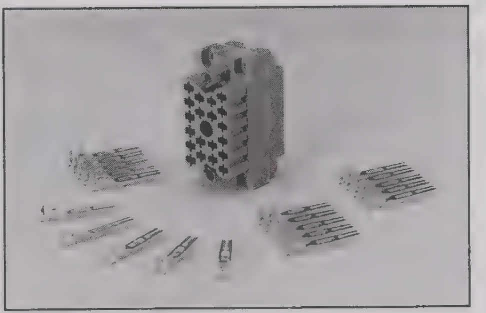
Model 7164-KIT: 50-pin D-Sub connector for assembly of custom cables and harnesses compatible with Models 7164-D and 7164-M 20-Channel Scanner Cards.



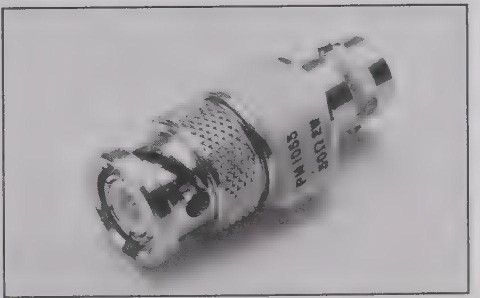
Model 7164-MTR: 50-pin mass terminated receptacle for custom interface and patch panels compatible with 7164-MTC.



Model 7169-KIT: 20-pin connector body and contacts for assembly of custom cables and harnesses compatible with Model 7169 20 Form C Switch Card.



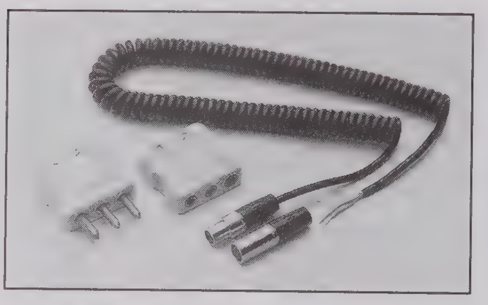
Model 7169-MTR: 20-pin bulkhead connector body and contacts for custom interface and patch panels compatible with Model 7169 20 Form C Switch Card.



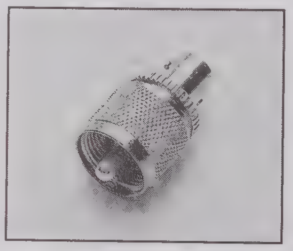
Model 7755 50Ω Feed-Through Terminator: BNC-to-BNC adapter for terminating RG58 cable in its characteristic impedance. VSWR <1.1, DC-250MHz.

Connectors and Adapters

Model 8691 RTD Connector Kit: Contains one male 4-wire connector, one female 4-wire connector with attached coiled cable (mates with connector on 1951), and male and female 3-wire adapters. Extended cable length: 1.5m (5 ft.).

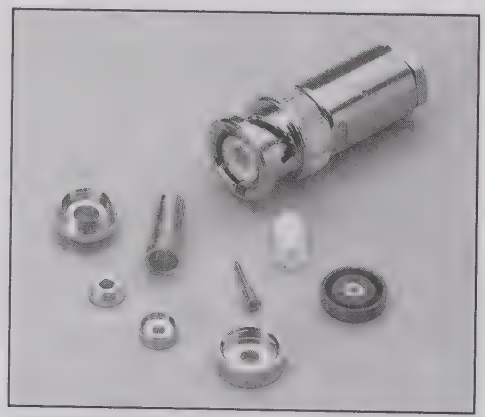


Model CS-115 UHF-BNC Adapter: Permits using Model 610C with accessories having BNC connectors.



Model CS-141: 2-slot male triax cable mount connector for use with SC-22 cable. Mates to Models 220, 224, 263, 602, 614, and 617.

Model CS-631: 3-slot male triax cable mount connector for use with SC-22 cable. Mates to Models 236, 237, 238, 486, 487, 7072, and 8006.



Test Fixtures

DEVICE COMPATIBILITY

MODEL		3323	6105	6426	8002A	8003	8006	8007	8008
Sheet Resistance			•						•
Volume Resistance			•						•
Axial Devices		•		•	•	•	•		
T0 18 Packages	4-Lead						•		
T0 5 Packages	4-Lead						•		
	8-Lead						•		
	10-Lead						•		
	12-Lead						•		
Dual In-Line Packages	≤24-Lead							•	
	≤28-Lead						•		
	≤48-Lead							•	
Prototyping Board								•	

KEITHLEY INSTRUMENT COMPATIBILITY

MODEL		3323	6105	6426	8002A	8003	8006	8007	8008
Electrometers, Picoammeters	428		•		•		•	•	•
	480		•		•		•	•	•
	485		•		•		•	•	•
	486				•		•	•	•
	487				•		•	•	•
	602		•		•		•	•	•
	610C		•		•		•	•	•
	614		•		•		•	•	•
	617		•		•		•	•	•
	642			•		•			
DMMs	169					•	•	•	
	175A					•	•	•	
	177					•	•	•	
	179A					•	•	•	
	193A					•	•	•	
	195A					•	•	•	
	196					•	•	•	
	197A					•	•	•	
	199					•	•	•	
Nanovoltmeters	155					•	•	•	
	181					•		•	
	182					•		•	
	263					•	•	•	
CV Meters	590						•	•	
	595						•	•	
SMUs	236				•	•	•	•	•
	237				•	•	•	•	•
	238				•	•	•	•	•
Sources	213						•	•	
	220					•	•	•	
	224					•	•	•	
	228A					•	•	•	
	230				•		•	•	
	247		•		•		•	•	
	261						•	•	
	263					•	•	•	
194A High Res. Digitizer							•		
3321, 3322 LCZ Meters		•							
580 Micro-ohmmeter						•	•		
707 Switch Matrix/7072								•	

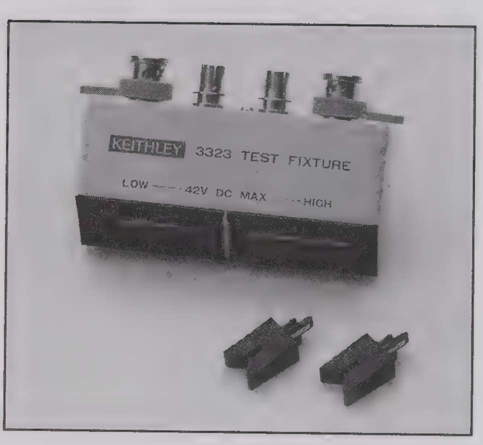
Test Fixtures

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

3323 Direct Test Fixture

The Model 3323 is designed for component measurement by directly inserting the component into the fixture. It can accommodate axial-lead components or radial-lead components without bending the component leads.

The 3323 is designed for use with Models 3321 and 3322 LCZ Meters.



- **Designed for surface and volume resistivity measurements.**
- **Accepts excitation voltages up to 1000V.**

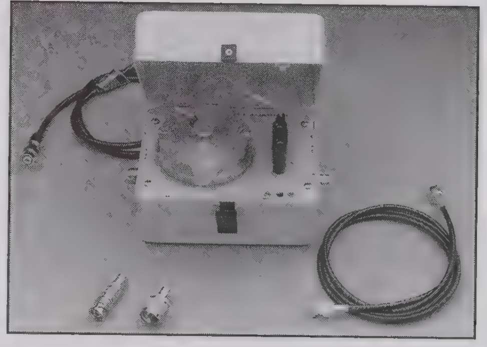
This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

6105 Resistivity Chamber

The Model 6105 Resistivity Chamber is a guarded test fixture for measuring volume and surface resistivities. This unit can be used with Keithley electrometers and voltage sources for direct measurement of volume resistivity to $10^{19}\Omega$-cm, and surface resistivity to $10^{18}\Omega$.

The 6105 accommodates samples 64 to 102mm in diameter and up to 6.4mm thick. Good sample contact is maintained between a spring loaded, guarded electrode and a one pound test weight assembly. An interlock switch automatically disables the excitation voltage upon opening the lid.

Cables supplied include one Model 32418 UHF to MHV cable, one Model 4801 BNC to BNC cable, one Model 6147 BNC to Triax adapter, and one Model CS-115 UHF to BNC adapter.



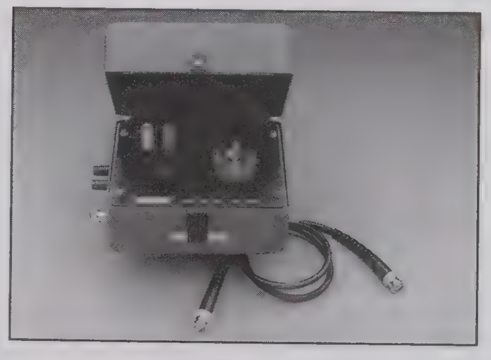
- **Guarded sapphire insulation offers the highest quality resistance and maintains maximum signal integrity.**
- **Designed for use with the Model 642 Electrometer, with less than 5×10^{-17}A input current.**

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

6426 Sapphire Insulated Test Box

The Model 6426 Sapphire Insulated Test Box is optimized for making high resistance measurements on small geometry parts, or semiconductor measurements on packaged devices. The unit has a sapphire insulated INPUT terminal to maintain $10^{16}\Omega$ input impedance.

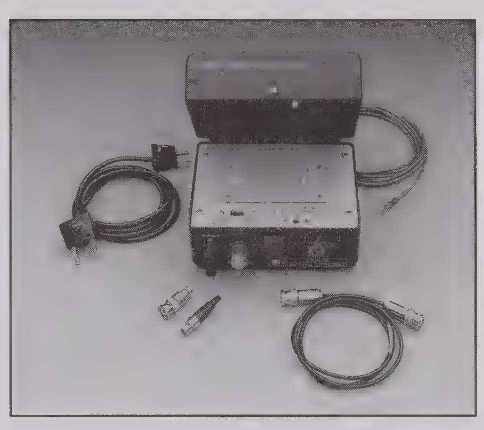
The 6426 mounts directly to the remote head of Keithley's Model 642 Digital Electrometer. It can be used to house an external feedback element, or to apply an external voltage to a device under test to determine leakage currents under the applied voltage stress. The 6426 also has provisions for connecting an external voltage source up to 42V.



8002A High Resistance Test Fixture

The Model 8002A High Resistance Test Fixture has been specifically designed to minimize leakage currents that can become a significant portion of a high resistance measurement if not controlled. Inputs are one pair of 5-way binding posts, and outputs are two 2-lug triax connectors.

Cables supplied include one Model CA-18-1 dual banana cable, and two Model 7024-5 triax cables.



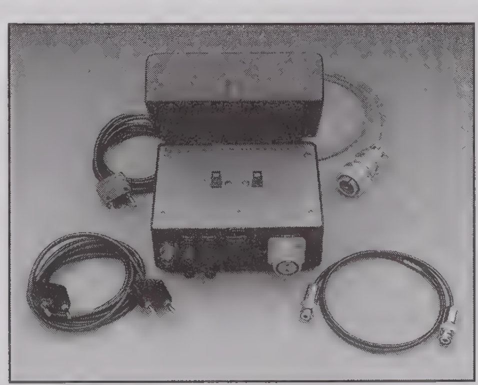
- **Unique design enables high resistance measurements up to 100TΩ.**

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

8003 Low Resistance Test Fixture

The Model 8003 Low Resistance Test Fixture provides separate 4-wire current source and voltage sensing terminals to increase the accuracy of very low resistance measurements. The input is one 2-lug triax connector, and outputs are two pairs of 5-way binding posts and a special low-thermal connector for nanovoltmeters.

Cables supplied include one Model 7024-5 triax cable, one Model 262-315 low-thermal cable, and two Model CA-18-1 dual banana cables.



- **Four-terminal device eliminates the effects of test lead and contact resistance.**

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

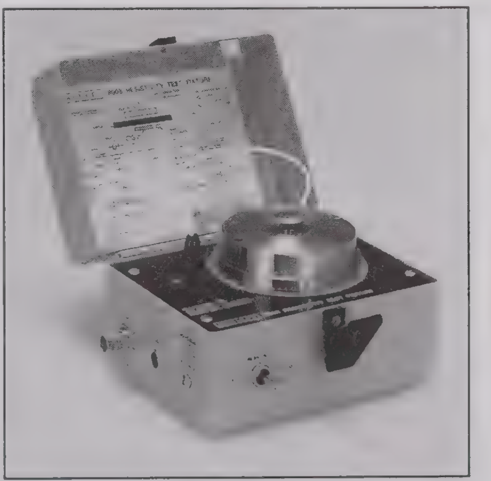
8008 Resistivity Chamber

The 8008 is a guarded test fixture for measuring volume and surface resistivities. It assures good electrostatic shielding and high insulation resistance. Use with Model 487 Picoammeter/Source or Models 236, 237 and 238 SMUs.

The 8008 accommodates sheet samples 64 to 102mm (2½ to 4 in.) in diameter and up to 6.4mm (¼ in.) thick. It maintains good sample contact with uniform 1 pound pressure on smooth parallel samples. A lid switch activates the voltage disable input on the rear panel of the 487 or SMU.

The 8008 permits direct measurement of volume resistivity up to $10^{18}\Omega$-cm (on samples 0.1cm thick) and surface resistivity up to $10^{17}\Omega$ in accordance with ASTM procedures.

Supplied accessories include one Model 7078-TRX-3 low noise triax cable and Model 8008-BAN, cable pair with safety banana plugs for use with Model 487.



- **Wide resistivity measurement range on sheet samples**

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only).**

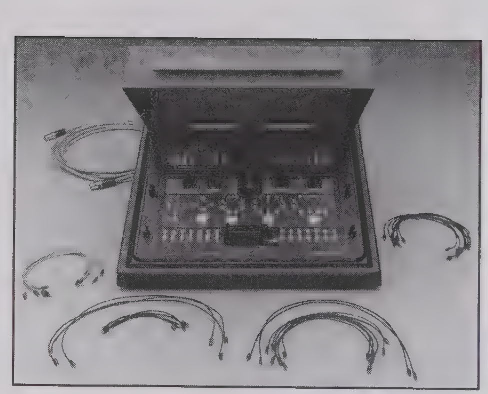
Test Fixtures

- **Versatile mini-jumper design incorporates eight different device sockets.**
- **Precise specifications maintain signal integrity throughout the test circuit.**
- **Versatile connections allow integration with a complete range of switches and instruments.**
- **Optimum design for use with Keithley SMUs (236, 237, 238).**

8006 Component Test Fixture

The Model 8006 Component Test Fixture was specifically designed for making sensitive measurements on standard package devices with minimal setup time. Individual components may be connected to one of eight device sockets, including axial, 4-, 8-, 10- and 12-lead T0, and 28-pin DIPs. Instrumentation may be easily integrated through the triax, BNC, or binding post connectors on the rear panel.

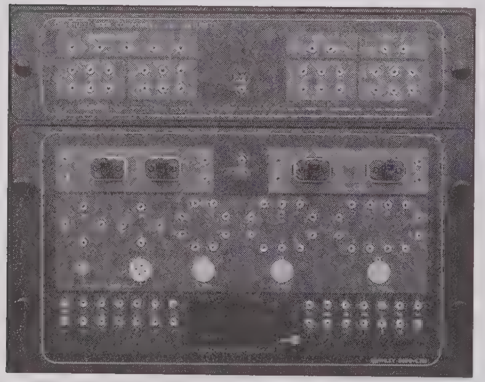
Signals from the test instruments are accessible at the test fixture's front panel. Mini jumper cables are provided to connect the signal to the appropriate device socket, which is also located on the front panel. This unique patch-board design allows for maximum versatility and the fastest possible setup times.



8006 comes complete with 40 jumpers and interlock cable.

The 8006 Test Fixture maintains accuracy throughout the test circuit with greater than 100TΩ $(10^{14}\Omega)$ path isolation, 4-wire connections, guarded jumpers, gold contacts and interconnects, and less than 100fA offset current. A hinged lid covers the component panel to provide a light-tight and shielded measurement.

The versatility of this unit makes it the ideal instrument for labs with a variety of DC characterization needs. Its wide range of operation, up to 1100V and 1A, and unique mini jumper interconnect scheme, enables a wide variety of tests to be performed. When there is a need to step through several tests on the same device, a switch may be integrated into the system. Keithley offers three switch mainframes with a wide selection of switching cards to meet the needs of most applications.



Versatile front panel allows testing of many different components.

Rear panel has triax, BNC, and binding post connectors.

This product is available with an **Extended Warranty**. See page 221for complete ordering information, or call **1-800-552-1115 (U.S. only).**

DEVICE SOCKET CONFIGURATION: 20mm and 30mm axial (Kelvin); 4-pin T0-18; 4-, 8-, 10-, 12-pin T0-5; 28-pin DIP (0.100 in. pin spacing, 0.300 to 0.600 in. wide, zero insertion force, replaceable).

CONNECTOR TYPE: Three-lug triax (12), isolated BNC (2), 5-way binding posts (5), safety ground terminal (1), safety interlock (1).

MAXIMUM COMMON MODE VOLTAGE FROM CHASSIS:
Triax Inner Shield: 1100V peak.
BNC Shell: 30V rms (DC to 60 Hz).
5-Way Binding Posts: 1100V peak

MAXIMUM SIGNAL VOLTAGE: 1100V peak, signal or guard to any signal, guard, panel shield, or module shield (except 600V peak, any signal to its own guard).

MAXIMUM SIGNAL CURRENT: 1A peak.

OFFSET CURRENT: <100fA.

PATH ISOLATION (using Triax or BNC connectors and cables):
Resistance:
Axial and Teflon Sockets: >100TΩ (>10,000TΩ typical*).
DIP Socket: >1TΩ (>100TΩ typical*).
Capacitance (nominal):
Axial Sockets: 0.2pF.
Teflon Sockets: 1pF.
DIP Socket: 3pF.

CROSSTALK @ 1MHz (typical)*: –70dB (50Ω source and measure).

3dB BANDWIDTH (typical)*: 4MHz (50Ω source and measure).

INSERTION LOSS @ 1 MHz (typical)*: 0.3dB (50Ω source and 1MΩ measure).

EFFECTIVE PATH RESISTANCE (w/4-wire Kelvin connections): Axial Sockets: <100µΩ (<10µΩ typical). **Teflon and DIP Sockets:** <20mΩ.

ENVIRONMENT: Operating: 0° to 50°C, <70% non-condensing R.H. up to 35°C. **Storage:** –25° to +70°C.

DIP SOCKET OPERATING LIFE: >25,000 open-close cycles.

LID INTERLOCK SWITCHING: <28VDC, 50mA.

DIMENSIONS, WEIGHT: 140mm high × 300mm wide × 300mm deep (5½ in. × 12 in. × 12 in.). Net weight 3.2kg (7 lbs. 2 oz.).

ACCESSORIES SUPPLIED:
Instruction manual

236-ILC-3	Interlock Cable, 3m (10 ft)
8006-MJS-1	Red Teflon Mini Jumper (10)
8006-MJS-2	Black Teflon Mini Jumper (10)
8006-MJS-3	Blue Teflon Mini Jumper (10)
8006-MJG	Guarded Teflon Mini Jumper (8)
8006-MJC	Red/Black Pair of Teflon Clip Jumpers
8007-GND-3	Safety Ground Wire

ACCESSORIES AVAILABLE

4801	Low-Noise Coax Cable, 1.2m (4 ft.)
7078-TRX-3	Triax Cable (3-lug), 1m (3 ft.)
7078-TRX-10	Triax Cable (3-lug), 3m (10 ft.)
8006-CTM	Component Test Module

*At room ambient conditions (18° to 28°C, <40% R.H.).

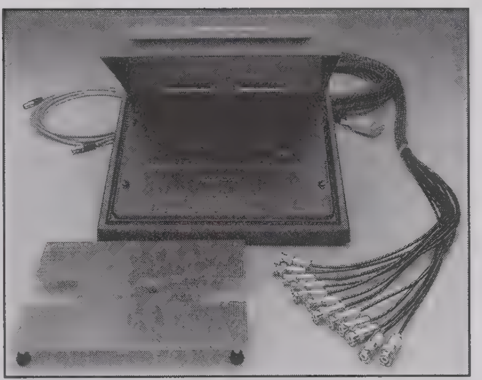
Except where noted, specifications assume: Any socket, guarded measurement configuration, including guarded jumpers and 1m external triax cables.

The 8007 Semiconductor Test Fixture assures accurate measurement data for DC characterization of packaged devices. This test fixture provides a convenient means of making sensitive measurements on Dual In-line Packages (DIPs) of 0.3 or 0.6 inch centers and up to 48 pins with the 24 or 48 pin socket. The prototyping board may be installed on the front panel for customized testing of packages with up to 72 pins.

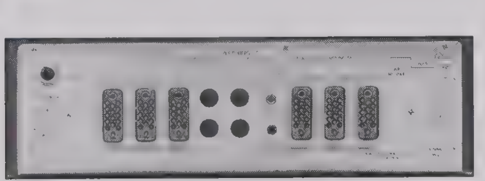
Accuracy is maintained to the DUT with isolation of more than 1TΩ. Offset current for the 8007 is less than 1pA, while maximum signal voltage is 200V with 1A peak current. A hinged cover provides light-tight and shielded measurements. 72 ferrite beads are also included for custom applications when DC tests are performed on active devices and some decoupling is required.

The 8007 is a convenient and accurate test fixture that reduces the setup time and complicated connections required for characterization of packaged components. It can improve the efficiency of test procedures in a wide range of applications, including device characterization, parametric test, component evaluation and incoming inspection.

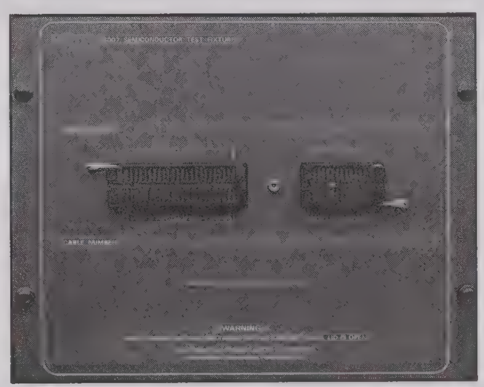
The 8007 is connected to Keithley's Model 707 switching system via triax-to-M series connectors, which are conveniently bundled and labeled in groups of 12 connections for simple interconnects to the 7072 card. Test signals are routed from the back panel to two standard DIP, Zero Insertion Force (ZIF) sockets.



8007 includes prototyping PC board and connecting cables.



Rear panel of 8007 has 6 mass termination connectors.



8007 has 24- and 48-pin device sockets.

- **Precise specifications maintain signal integrity throughout the test circuit.**
- **24- and 48-pin DIP sockets accept a wide range of devices.**
- **Prototyping board included for easily accommodating custom devices up to 72 pins.**
- **Optimum design for use with the semiconductor matrix switching card (7072).**

This product is available with an **Extended Warranty**. See page 221 for complete ordering information, or call **1-800-552-1115 (U.S. only)**.

DEVICE SOCKET CONFIGURATION: 1 each, 24- and 48-pin gold contact DIP sockets (0.100 in. pin spacing, 0.300 to 0.600 in. wide, zero insertion force, replaceable).

CONNECTOR TYPE: 6 mass termination connectors (12 coax connections each, 72 total measurement pathways).

MAXIMUM SIGNAL VOLTAGE: 200V peak, signal or guard to any signal, guard, sub-chassis, or chassis.

MAXIMUM SIGNAL CURRENT: 1A peak.

OFFSET CURRENT **(18° to 28°C, <60% R.H.)**: <1pA (0.1 pA typical @ <40% R.H.).

PATH ISOLATION **(18° to 28°C, <60% R.H.)**:
  Resistance: >1TΩ (10TΩ typical @ <40% R.H.).
  Capacitance (nominal): 2pF.

CROSSTALK @ 1MHz **(typical)***: –60dB (50Ω source and measure).

3dB BANDWIDTH **(typical)***: 4MHz (50Ω source and measure).

INSERTION LOSS @ 1 MHz **(typical)***: 0.1dB (50Ω source and 1 MΩ measure).

PATH RESISTANCE: <1Ω.

ENVIRONMENT: **Operating:** 0° to 50°C, <70% non-condensing R.H. up to 35°C. **Storage:** –25° to +70°C.

SOCKET OPERATING LIFE: >25,000 open-close cycles.

LID INTERLOCK SWITCHING: <28VDC, 50mA.

DIMENSIONS, WEIGHT: 140mm high × 305mm wide × 292mm deep (5½ in. × 12 in. × 11½ in.). Net weight 3.5kg (7 lbs., 12 oz.).

ACCESSORIES SUPPLIED:

Instruction manual

236-ILC-3	Interlock Cable, 3m (10 ft.)
8007-GND-3	Safety Grounding Cable
8007-MTC-3	3-lug triax to mass termination connector cable assembly, 3m (10 ft.), two supplied
8007-PTB	Prototyping PC Board

ACCESSORIES AVAILABLE:

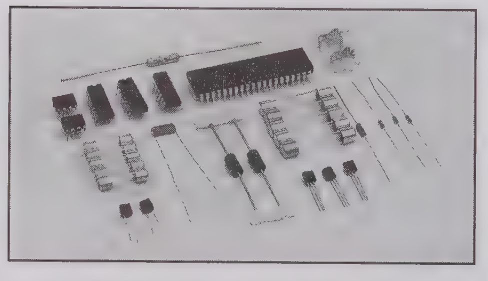
236-ILC-3	Interlock Cable, 3m (10ft.)
8007-MTC-3	3-lug triax to mass termination cable assembly, 3m (10ft.)
8007-PTB	Prototyping PC Board

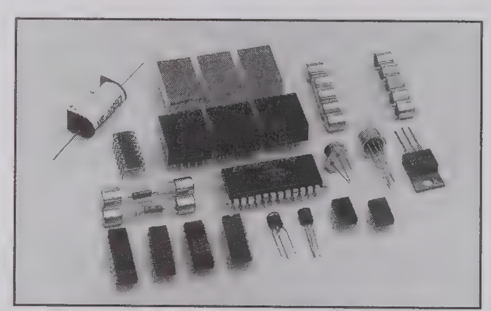
Specifications are for guarded measurement configuration, including external cables.

Calibration, Maintenance, Spare Parts

MODEL	NAME	USE WITH:
1699	Spare Parts Kit	169 DMM
1755	Calibration Interface	175A, 197A, 485, 580
1759	Spare Parts Kit	175A DMM
1779	Spare Parts Kit	177 DMM
1815	Maintenance Kit	181 Nanovoltmeter
1979	Spare Parts Kit	197A DMM
5905	Calibration Sources	590 CV Analyzer
5906	Calibration Sources	590 CV Analyzer
5907	Calibration Sources	590 CV Analyzer (cable and matrix)
5909	Model 82 Calibration Sources	Model 82, 82-DOS CV Systems
5955	Calibration Sources	595 Quasistatic CV Meter
6421	Refill Desiccant Paper Pack	642, 642 LNFPA Electrometers
7078-PEN	Programming Light Pen	707 Switching Matrix

Model 1699: Spare parts for Model 169.

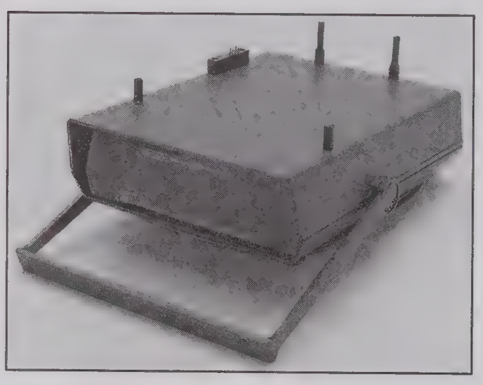


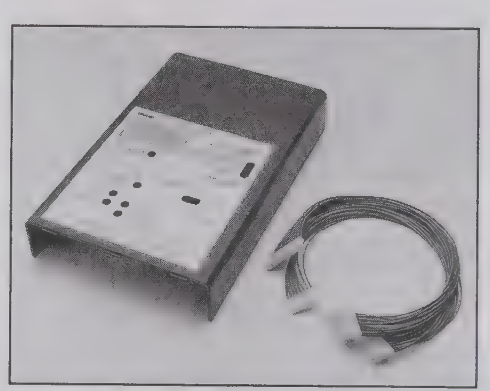


Model 1779: Spare parts for Model 177.

Model 1755 Calibration Interface permits automated IEEE-488 based verification and calibration of 175A, 197A, 485, 580 without installed interfaces. An IEEE-488 interface must be installed in the 1755 for the specific instrument under test.

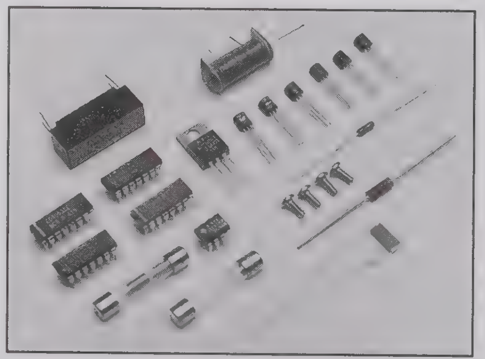
Dimensions: 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.).



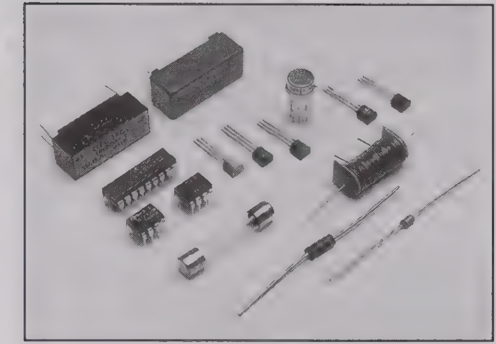


Model 1815 Maintenance Kit: Contains a calibration cover and two extender cables. Cover stabilizes internal temperature; cables permit easy access to 181's PC boards.

Model 1759: Spare parts for Model 175A.



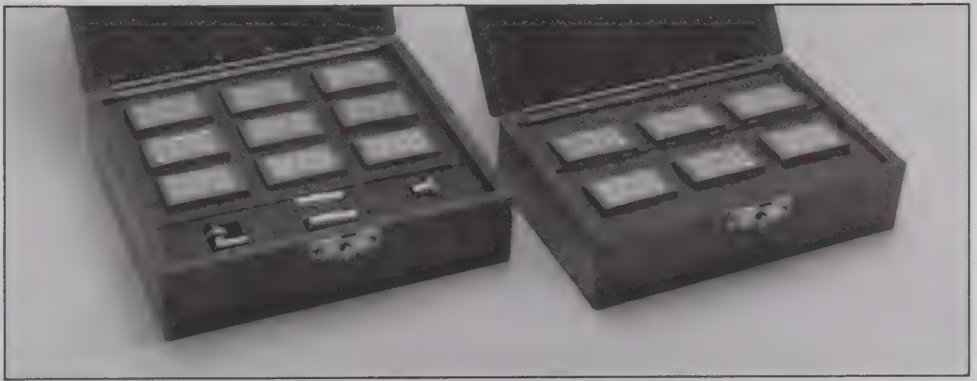
Calibration, Maintenance, Spare Parts

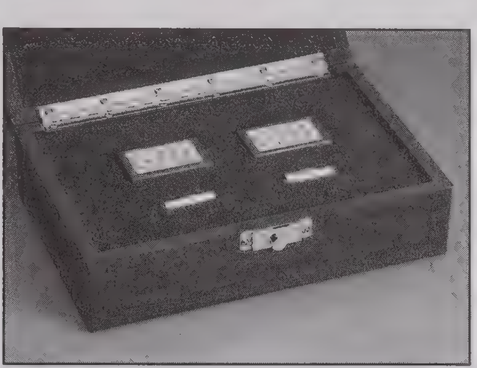


Model 1979: Spare parts for Model 197A.

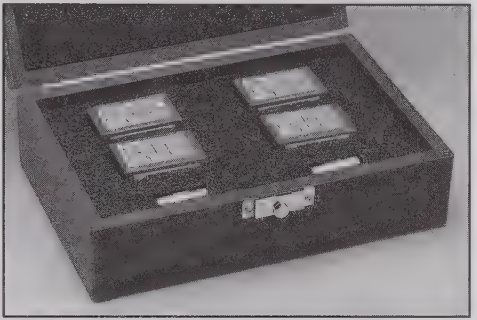
Model 5905: Calibration sources for Model 590/1M. Includes 18pF, 180pF, 1.8nF, 4.7pF, 47pF, 470pF capacitance sources and 180μS, 1.8mS, 18mS conductance sources. Also includes CS-566 right angle male-to-female BNC connector, CS-567 female BNC shorting cap, and 5900-313 storage case.

Model 5906: Calibration sources for Models 590/1M, 590/100k, 590/100k/1M, and 5904. Includes 1.5pF, 18pF, 180pF, 1.8nF, 18nF, 0.5pF, 4.7pF, 47pF, 470pF, 4.7nF capacitance sources and 1.8μS, 18μS, 180μS, 1.8mS, 18mS conductance sources. Includes two storage cases.

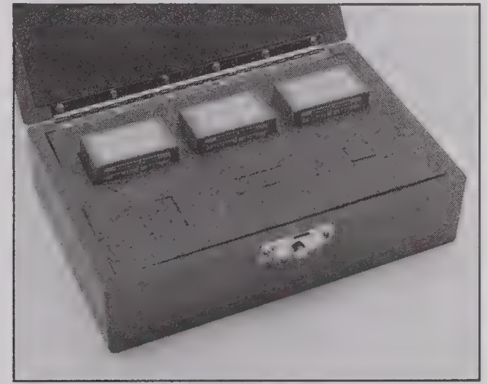




Model 5907: Calibration sources to calibrate cable and matrix. Includes 1.8nF and 470pF capacitance sources, 2 BNC female-to-female barrels (CS-565), and 5900-312 storage case.



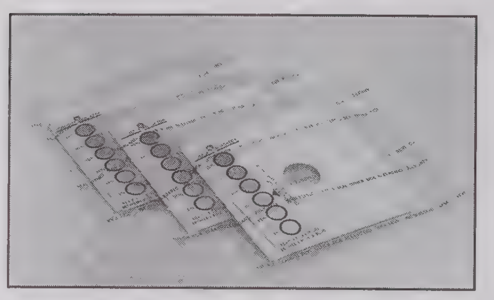
Model 5909 Calibration Sources for Model 82. Includes 1.8nF, 470pF, 180pF, and 47pF capacitance sources, two female-to-female barrels (CS-565), and storage case.



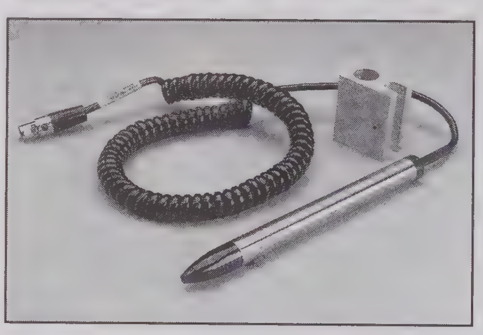
Model 5955: Calibration sources for Model 595. Includes 18nF, 1.8nF, 180pF capacitance sources and storage case.

Calibration, Maintenance, Spare Parts

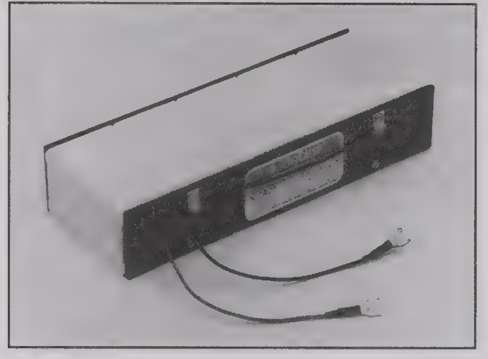
Model 6421: Refill desiccant paper pack for Model 642. One piece at a time may be installed in the remote head as needed. Each of the three pieces is individually packaged in its own moisture resistant bag.



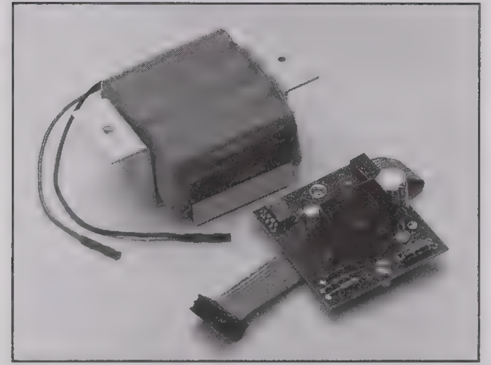
Model 7078-PEN Light Pen Programming Accessory plugs into the front panel of a Model 707 Switching Matrix and is used for interactive control and programming of the relay and memory states of the instrument.



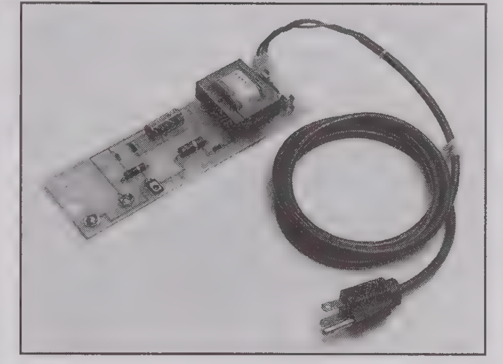
MODEL	NAME	USE WITH:
1489	Replacement Battery Pack	148
1758	Rechargeable Battery Pack	175A, 485
1766	Battery Eliminator	169
1788	Rechargeable Battery Pack	177, 179A, 480
1978	Rechargeable Battery Pack	197A, 580
6428	Battery Adapter	642



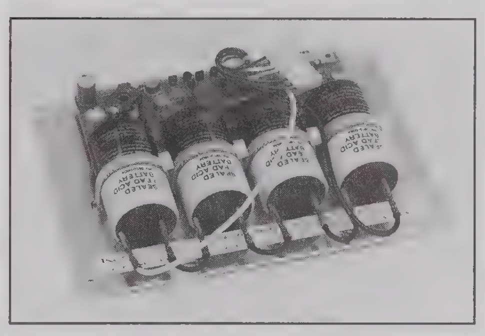
Model 1489 Battery Pack: Replacement nickel-cadmium 6V battery pack for Model 148. 14 hours full charge to complete discharge. The battery lasts about 1000 rechargeable cycles.



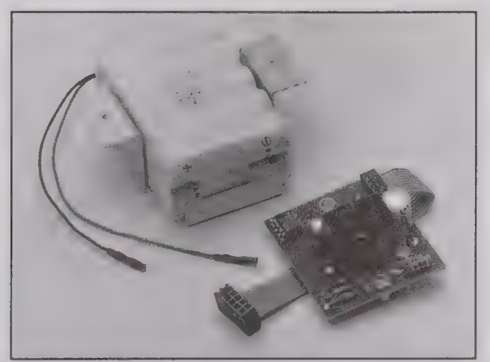
Model 1758 Rechargeable Battery Pack: For Models 175A and 485. Provides 6–8 hours operation from full charge; recharges within 10 hours and is field installable.



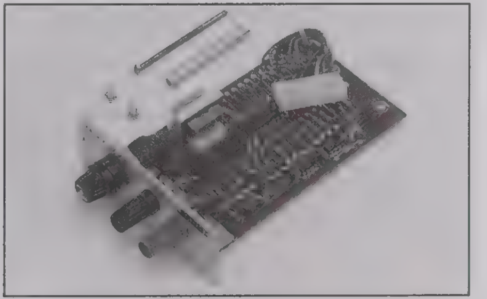
Model 1766 Battery Eliminator: Converts Model 169 to line cord operation. 105V AC to 250V AC; 10VA max; 50Hz or 60Hz; 1/32A Slo Blo fuse (250V). 0.45kg (1 lb.). Field installable.



Model 1788 Rechargeable Battery Pack: 6 hours operation from full charge; 14 hour recharge; field installable. 0.9kg (2 lbs.). Use with 177, 179A, 480.



Model 1978 Rechargeable Battery Pack: Allows off-line or field operation of the Model 197A or 580. Provides 5–7 hours operation from full charge. Contains its own charging circuit and can be recharged within 10 hours. Field installable.



Model 6428 Battery Adapter: For operating 642 from external 12V battery; field installable.

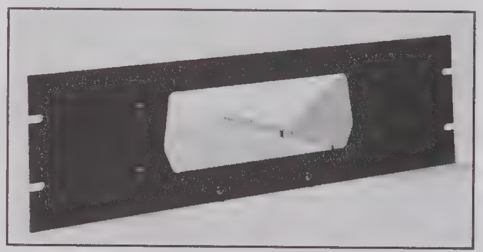
Racks and Rack Kits

INSTRUMENT MODEL NUMBER	SINGLE FIXED	SINGLE SLIDE*	DUAL FIXED	DUAL SLIDE	TYPE OF MOUNT
169 175A 175AV 177 179A 197A 480 485 580	1010		1017		Shelf
182 428 486 487	4288-1		4288-2		Side
193A 194A 236 237 238	1938	1939			Bracket w/handles
195A 196 220 224 230 230-1 263 595 614 617 705 740 775A	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
199	1998-1		1998-2		Side
228A 590	2288	2289A			Bracket w/handles
261	4003A				Side
427 642	2000				Side
706	7068	7069			Bracket w/handles
707	Included	7079			Side
3321 3322 3933A 3910 3930A 3940	3900-1		3900-2		Side

*Slide rack mount kits are not compatible with equipment cabinet Models 8000-10 and 8000-14.

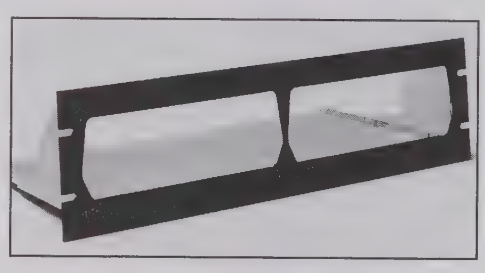
Keithley rack mounting kits contain instructions and all hardware necessary for mounting many Keithley products in any EIA RS-310-C standard 19-inch system cabinet such as Keithley's Model 8000, 8000-10 or 8000-14. Described here are the wide range of kits available and the various instruments that fit each kit. Shelf-type racks include a base plate for the mounted instrument(s); other kits are side-mounted and attach the instrument to the side of the rack. Dimensions shown are for the assembled kit and, unless otherwise noted, do not include dimensions of mounted instruments.

NOTE: Enclosures which do not conform to EIA RS-310-C may require special adapting hardware. Consult the enclosure manufacturer's catalog.



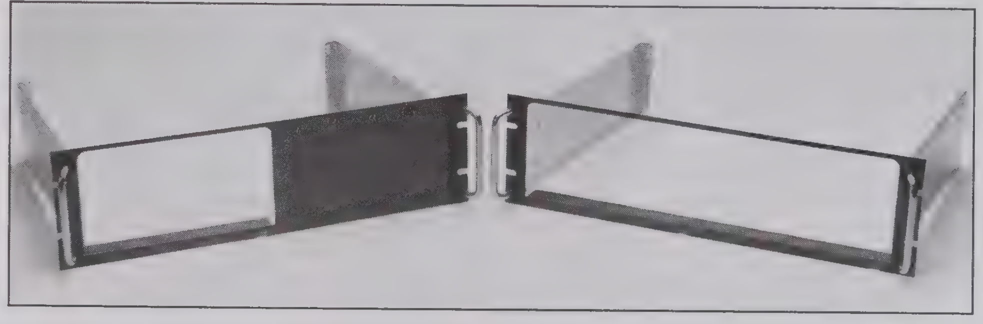
Model 1010 is a shelf-type kit for mounting a single Keithley Model 169, 175A, 177, 179A, 197A, 480, 485, or 580.

Dimensions: 132mm high × 483mm wide × 254mm deep (5¼ in. × 19 in. × 10 in.).



Model 1017 is similar to Model 1010 but mounts any two Models 169, 175A, 177, 179A, 197A, 480, 485, and 580.

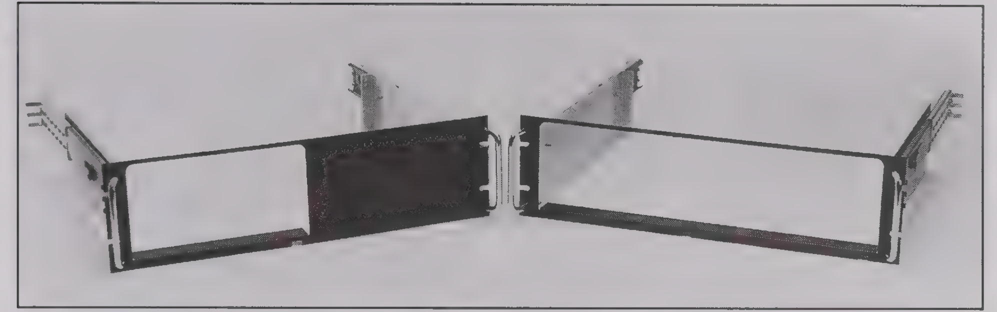
Dimensions: 132mm high × 483mm wide × 254mm deep (5¼ in. × 19 in. × 10 in.).



Models 1019A-1 and 1019A-2 are fixed shelf-type rack mounting kits for half-rack, 127mm (5 in.) high instruments (see Selector Guide above). The 1019A-1 kit mounts one instrument and the 1019A-2 kit mounts two.

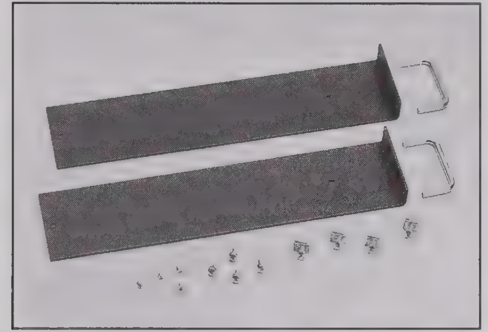
Dimensions: 132mm high × 483mm wide × 356mm deep (5¼ in. × 19 in. × 14 in.).

Racks and Rack Kits

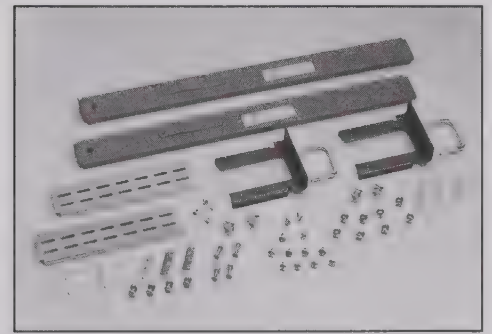


Models 1019S-1 and 1019S-2 are sliding shelf-type rack mounting kits for half-rack, 127mm (5 in.) high instruments (see Selector Guide above). The 1019S-1 kit mounts one instrument and the 1019S-2 kit mounts two.

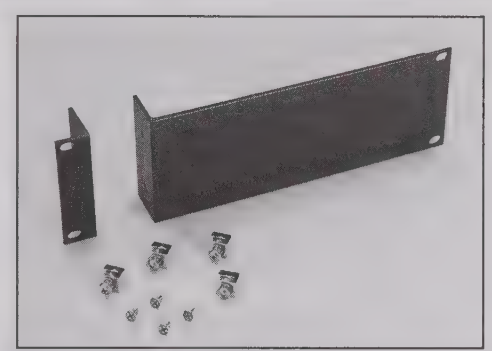
Dimensions: 132mm high × 483mm wide × 356mm deep (5¼ in. × 19 in. × 14 in.).



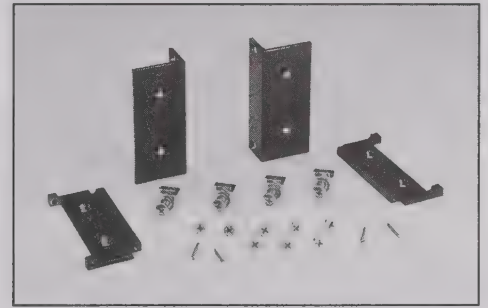
Model 1938 Fixed Rack Mount Kit consists of 2 flanged brackets and hardware for mounting the Model 193A, 194A, 236, 237, or 238 in a standard 19 in. equipment cabinet. Can be used with Model 8000, 8000-10 or 8000-14. 89mm (3½ in.) height.



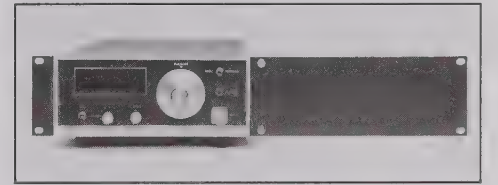
Model 1939 Slide Rack Mount Kit consists of 2 sets of flanged brackets, equipment slides, and hardware for mounting the Model 193A, 194A, 236, 237, or 238 in a standard 19 in. equipment cabinet. Can be used with Model 8000. 89mm (3½ in.) height.



Model 1998-1 Single Fixed Rack Mounting Kit: Consists of one rack ear, a dress panel, and hardware for mounting the Model 199 System DMM in a standard 48.3cm (19 in.) equipment cabinet. **Height:** 89mm (3½ in.).

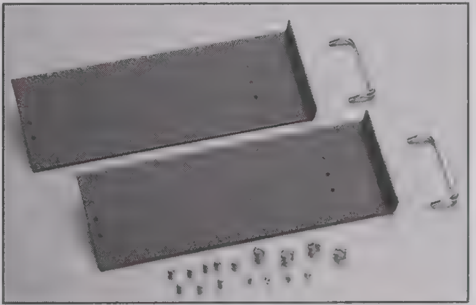


Model 1998-2 Dual Fixed Rack Mounting Kit: Consists of two rack ears, two middle brackets, and hardware for mounting two Model 199 System DMMs side-by-side in a standard 48.3cm (19 in.) equipment cabinet. **Height:** 89mm (3½ in.).



Model 2000 enables single rack mounting for Models 427 and 642. Includes a cover plate for the open area.

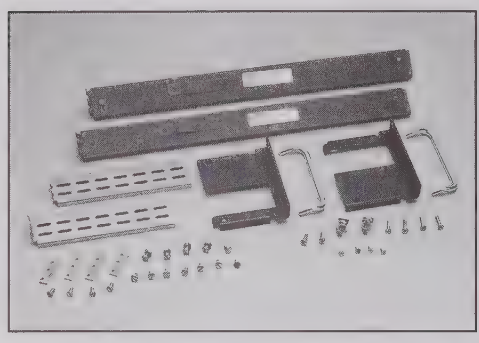
Dimensions (incl. instrument): 89mm high × 483mm wide × 400mm deep (3½ × 19 × 15¾ in.).



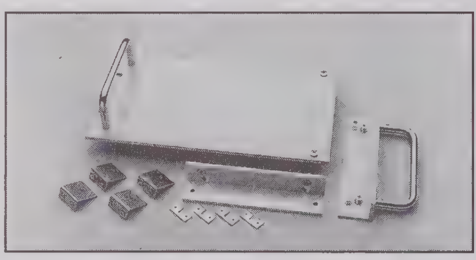
Model 2288 Fixed Rack Mount Kit: Consists of 2 flanged brackets and hardware for mounting the Model 228 or 228A in a standard 19 in. equipment cabinet. Can be used with Model 8000, 8000-10 or 8000-14. 132mm (5¼ in.) height.

Racks and Rack Kits

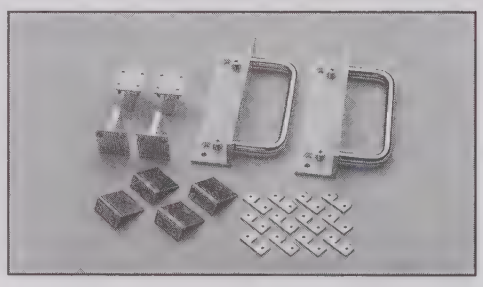
Model 2289A Slide Rack Mount Kit: Consists of 2 sets of flanged brackets, equipment slides, and hardware for mounting the Model 228 or 228A in a standard 19 in. equipment cabinet. Can be used with Model 8000. 132mm (5¼ in.) height.



Model 3900-1: Single-unit rack mount kit for Models 3321, 3322, 3910, 3930A, 3933A, and 3940. Includes all necessary hardware to mount one unit in a 5¼-inch high rack space.

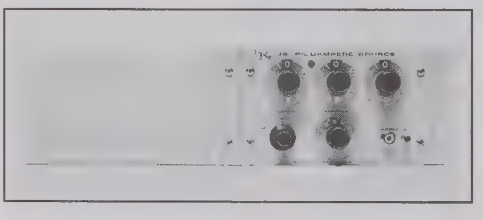


Model 3900-2: Dual rack mount kit for Models 3321, 3322, 3910, 3930A, 3933A, and 3940. Includes all necessary hardware to mount two units side by side in a 5¼-inch high rack space.

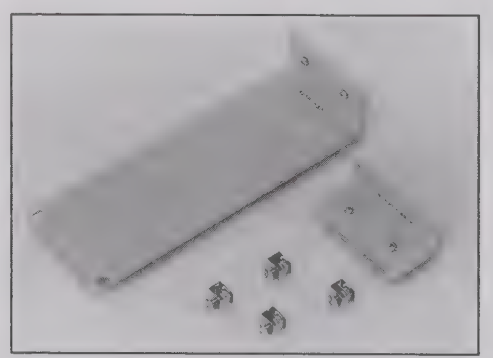


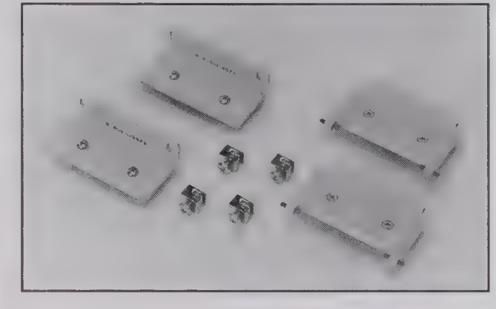
Model 4003A is a single side-mounted kit used to mount one Model 225, 261, or 26000 series.

Dimensions (including mounted instruments): 132mm high × 43mm wide × 311mm deep (5¼ × 19 × 12¾ in.).

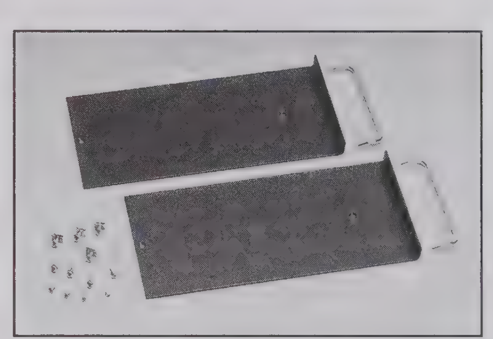


Model 4288-1 Fixed Rack Mount Kit: Enables rack mounting of one Model 428, 486, 487, or 182. Height: 88mm (3½ in.).

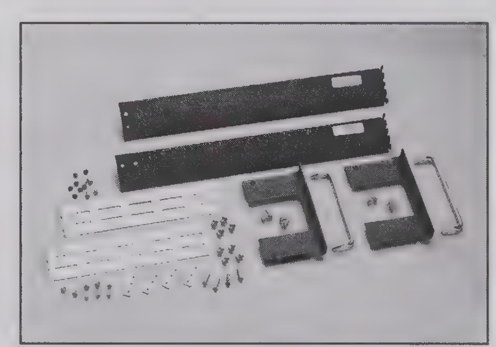




Model 4288-2 Fixed Rack Mount Kit: Enables rack mounting of one or two Models 428, 486, 487, or 182. Height: 88mm (3½ in.).

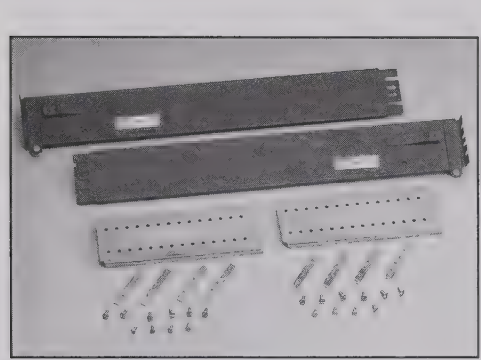


Model 7068 Fixed Rack Mount Kit: Two 7 in. flanged brackets and hardware for mounting Model 706 in a standard 19 in. equipment cabinet. Can be used with Model 8000, 8000-10 or 8000-14.

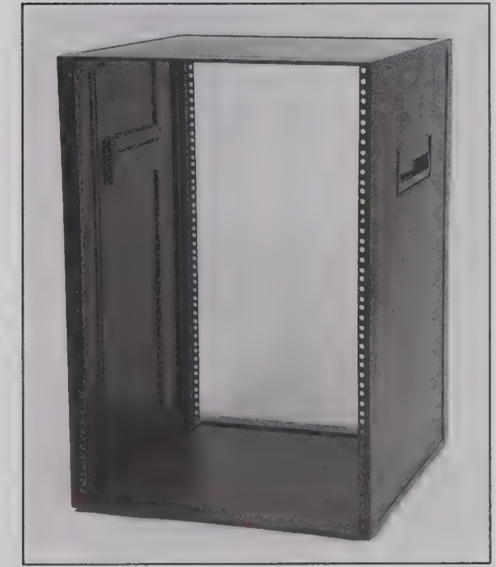


Model 7069 Slide Rack Mount Kit: Two sets of flanged brackets, slides, and hardware to mount Model 706 in standard 19 in. equipment cabinet. Can be used with Model 8000.

Racks and Rack Kits

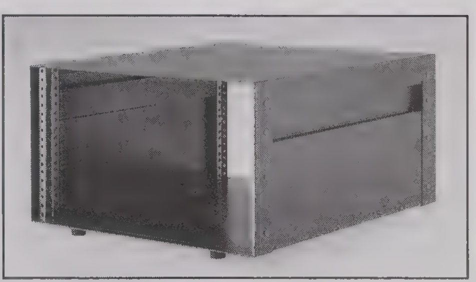


Model 7079 Slide Rack Mount Kit: Two sets of flanged brackets, slides, and hardware to mount Model 707 in standard 19 in. equipment cabinet. Can be used with Model 8000.



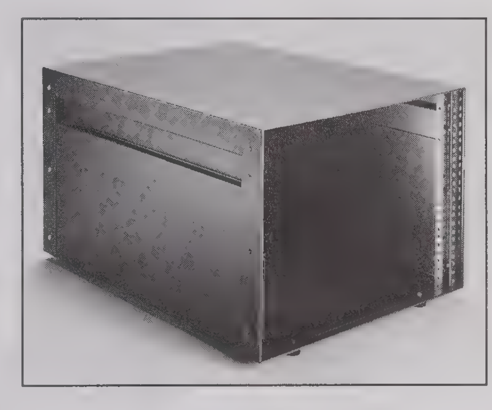
Model 8000 is a 28 in. high equipment cabinet that is open on both ends. It will accept all Keithley rack mounting kits as well as most rack kits provided with other instrumentation. The dark brown 8000 comes fully assembled, with handles permanently installed on each side. 100 chrome Phillips head screws with mylar washers and clip nuts are provided for instrument mounting. Rack mounting kits are available separately.

Dimensions: 711mm high × 483mm wide × 533mm deep (28 in. × 19 in. × 21 in.).



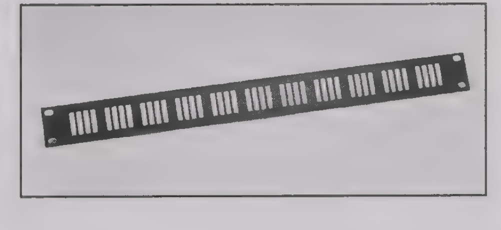
Model 8000-10: A standard 10 inch high, 19 inch wide equipment cabinet for enclosing instrumentation for bench or automated test system application. The Model 8000-10 will accept most Keithley mainframe models and fixed rack mount kits. The cabinet is supplied with rubber feet for benchtop applications, and the sturdy steel construction will support additional instrumentation stacked on top.

Dimensions: 254mm high × 483mm wide × 533mm deep (10 in. × 19 in. × 21 in.).



Model 8000-14: A standard 14 inch high, 19 inch wide equipment cabinet for enclosing instrumentation for bench or automated test system application. The Model 8000-14 will accept all Keithley mainframe models and fixed rack mount kits. The cabinet is supplied with rubber feet for benchtop applications including enclosure of the 707 Switching Matrix, and the sturdy steel construction will support additional instrumentation stacked on top.

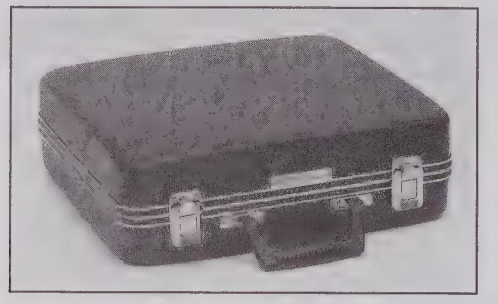
Dimensions: 356mm high × 483mm wide × 533mm deep (14 in. × 19 in. × 21 in.).



Model 25790 Vented Panel: Provides ventilation between instruments mounted in 483mm (19 in.) wide instrument racks. Height 44mm (1¾ in.). Color: Brown.

Carrying Cases

MODEL	NAME	USE WITH:
1684	Hard Shell Carrying Case	169, 175A, 177, 179A, 197A, 480, 485, 580
1686	Vinyl Carrying Case	169, 175A, 177, 179A, 197A, 480, 485, 580
5801	Test Lead Pouch	169, 175A, 177, 179A, 197A, 480, 485, 580



Model 1684 Hard Shell Carrying Case: Hard vinyl case, 100mm × 330mm × 356mm (4 in. × 13 in. × 14 in.) has fitted foam insert with room for one of Models 169, 175A, 177, 179A, 197A, 480, 485, and 580. Also room for an instruction book and small accessories.

Model 1686 Vinyl Carrying Case: A soft, lightweight carrying case for Models 169, 175A, 177, 179A, 197A, 480, 485, and 580. An external pocket provides space for test leads.

Dimensions: 368mm high × 241mm wide × 76mm thick (14½ in. × 9½ in. × 3 in.).

Model 5801: Test lead pouch for Models 5804, 5805, and 5806 test leads used with Model 580.

Keithley MetraByte/Asyst/DAC 206

Keithley Systems Division 214

Keithley Radiation Measurements Division ... 218

Other Keithley Divisions

Introduction to Data Acquisition

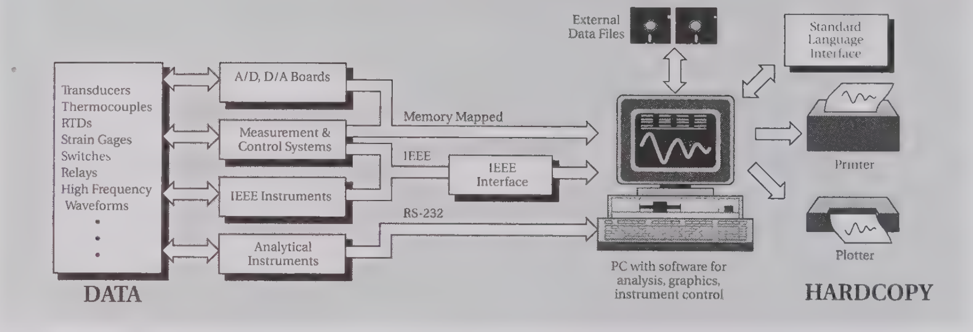
KEITHLEY METRABYTE/ASYST/DAC

Commitment to Customer Service

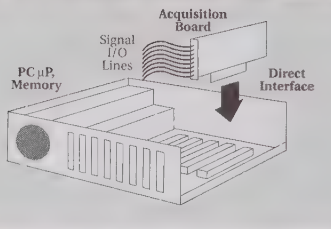
This information is only a brief guide to choosing your data acquisition solution. Much more help is available from our technical support group. With application engineers in the field, technical representatives in all major cities, and hardware and software technical support staff at the factory, Keithley offers the strongest customer support in the industry. Contact us at:

Keithley MetraByte/Asyst/DAC
440 Myles Standish Blvd.
Taunton, MA 02780
(508) 880-3000
Fax: (508) 880-0179

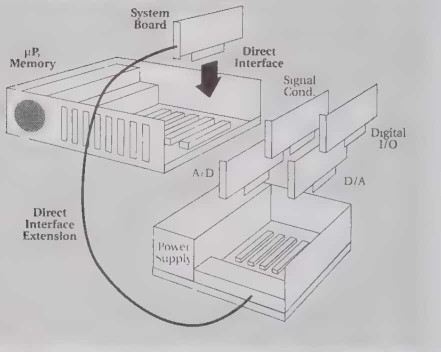
The PC-Based Workstation


Transducers
Thermocouples
RTDs
Strain Gages
Switches
Relays
High Frequency
Waveforms
DATA
A/D, D/A Boards
Measurement & Control Systems
IEEE Instruments
Analytical Instruments
Memory Mapped
IEEE
IEEE Interface
RS-232
External Data Files
Standard Language Interface
Printer
Plotter
PC with software for analysis, graphics, instrument control
HARDCOPY

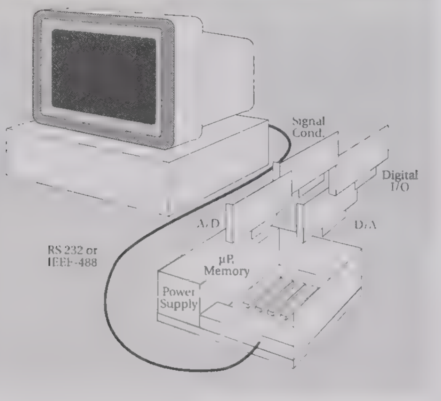
BOARDS


Acquisition Board
Signal I/O Lines
PC µP, Memory
Direct Interface

SYSTEMS


System Board
µP, Memory
Direct Interface
Signal Cond.
Digital I/O
A/D
D/A
Direct Interface Extension
Power Supply

SMART SYSTEMS


Signal Cond.
Digital I/O
A/D
D/A
RS 232 or IEEE-488
µP, Memory
Power Supply

Keithley MetraByte/Asyst/DAC offers the widest range of Data Acquisition & Control products designed for use with the IBM PC/XT/AT, IBM PS/2, MicroChannel and Macintosh computers and compatibles.

Keithley MetraByte/Asyst/DAC boards offer simplicity and low cost solutions for Data Acquisition, Control and Measurements. These boards are designed to plug directly into the PC bus. This structure allows them to rapidly respond to commands from the microprocessor. Direct Memory Access speeds acquisition and transfer of data to and from the memory. Expansion boards and boxes, digital I/O, relay boards and other accessory products enhance measurement and control applications by providing higher channel density, signal conditioning, and numerous control functions.

External systems like Workhorse, Series 500 and MetraBus offer more analog input channels and digital I/O. These systems use a direct parallel connection to the PC bus for fast response. Most systems are self-contained with their own power supply and compact chassis.

The Workhorse system is ideal for industrial control applications. The Series 500 offers the widest choice of analog I/O, making it well suited for laboratory automation and control. The MetraBus system provides the lowest cost per channel. All three systems offer optional IEEE-488 interfaces for greater distance or different computer use.

The Series 500 (Model 576) and MetraBus system (INTMDB-64) provide “smart” stand-alone capability. These systems include memory and a microprocessor to run the program, take and store data, and make decisions independently of the PC. The PC is then free to do other tasks, like collect data from other sources while the system is running.

The computer and data acquisition hardware that you choose determines the physical limits of your PC-based workstation or system. However, software is the crucial element that lets you control your hardware and lets your system achieve its potential. Keithley MetraByte/Asyst/DAC offers the widest choice of software, from utility software to complete high performance data acquisition, analysis and graphic packages like ASYST, EASYEST, and VIEWDAC.

In addition to high performance data acquisition and control boards and system products, Keithley MetraByte/Asyst/DAC offers many other product families to meet your needs.

The Personal Computer Instrumentation Products (PCIP) provide full instrument functions on a single plug-in board. Now you can turn your PC into an Oscilloscope, Digital Multi-Meter, Signal Generator, Programmable Resistance Source, Logic Analyzer or many other fine instruments. Designed for ease of use, these products provide a pop-up display screen, and the computer’s keyboard replaces the typical instrument knobs and buttons.

Keithley MetraByte/Asyst/DAC offers a fine assortment of communications boards for the IBM PC/XT/AT, PS/2 and MicroChannel computers and compatibles. Several IEEE-488 plug-in boards are offered, with full compatibility with IEEE-488-1978 specifications. RS-232, RS-422 and RS-485 boards are available for instrumentation, modem, printer, plotter and networking applications.

As you can see, Keithley offers the widest range of Data Acquisition and Control hardware and software products to meet your needs. It doesn’t matter if you’re in a laboratory making sophisticated fast measurements of an experiment, in a manufacturing environment where you’re required to measure and control many varied signals for production, or you simply need to make several instrument quality measurements and analyze the results. Your PC and our hardware and software products will simplify the task and give you the results you require, quickly and cost effectively.

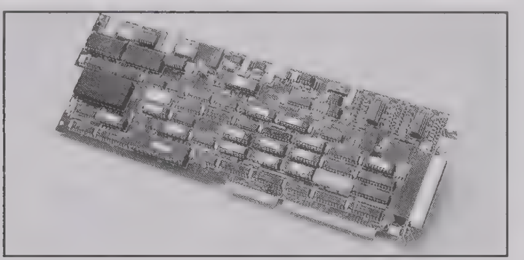
Call or write us for our latest PC-based Data Acquisition and Control product catalog, or send the convenient reply card in the back of this catalog.

High Performance Data Acquisition & Control Boards for IBM PC/XT/AT, PS/2 and MicroChannel Computers and Compatibles

- Analog & Digital I/O Boards
- Analog Output Boards
- Digital I/O Boards
- Channel Expansion Boards and Boxes
- Relay Output Boards
- Motor Control Boards
- Counter/Timer Boards

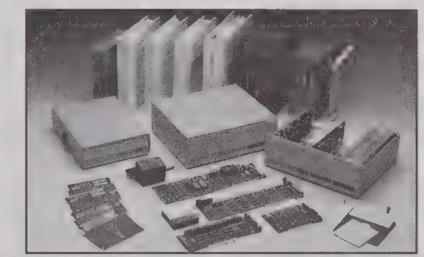
PCIP Personal Computer Instrumentation Products

- Digital Multimeter
- Digital Oscilloscope
- Voltage Calibrator
- Signal Generator
- Digital Logic Analyzer
- Counter/Timer
- Programmable Resistance Box
- Arbitrary Waveform Generator
- Programmable Power Supply



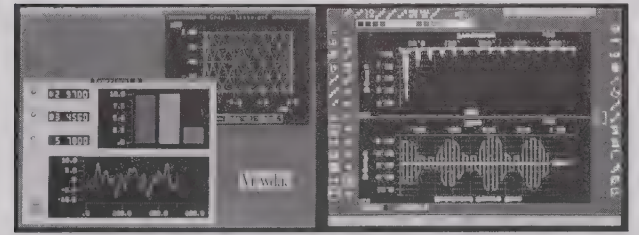
High Performance Data Acquisition I/O Boards:

- DAS-50 1,000,000 samples/s, 1 Megaword Memory Buffer
- DAS-40 250,000 samples/s, 2 Analog Outputs, 16 Digital I/O
- DAS-HRES 16-Bits resolution, 8-Channels, 2 Analog Outputs
- DAS-20 100,000 samples/s, 16-Channels, 16 Digital I/O



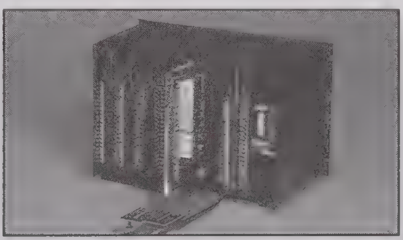
High Performance Measurement & Control Systems.

- 500A 10-slot Data Acquisition Chassis, up to 16-Bit Resolution
- 500P Portable Data Acquisition Chassis, 12V and 24V operation
- 576 GPIB (IEEE-488)Measurement & Control System, Device Dependent Command Programming, Alarms and Datalogging
- 575 Low Cost, High Performance System, Fully Software Programmable



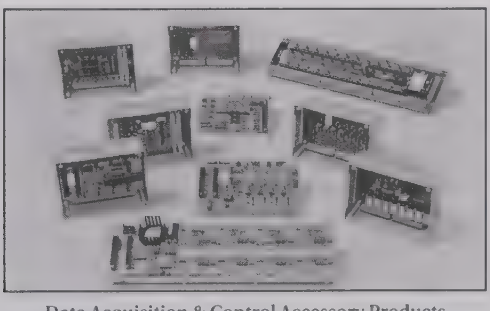
Powerful Data Acquisition & Control, Analysis and Graphics Software Packages

- ASYST High level programming language for maximum flexibility
- EASYEST Easy-to-use icon driven package
- VIEWDAC The only data acquisition package for the 386



Industrial Data Acquisition Systems

- Workhorse: Industrial Monitoring and Control System designed to work specifically with Personal Computers. The Workhorse provides up to 3,584 analog inputs, 1,024 digital I/O lines, with expansion slots.
- Full speed operation (2 microsecond) response time, for distances up to 4,000 feet.
- Easy to use Software Drive facilitates reading and writing data.



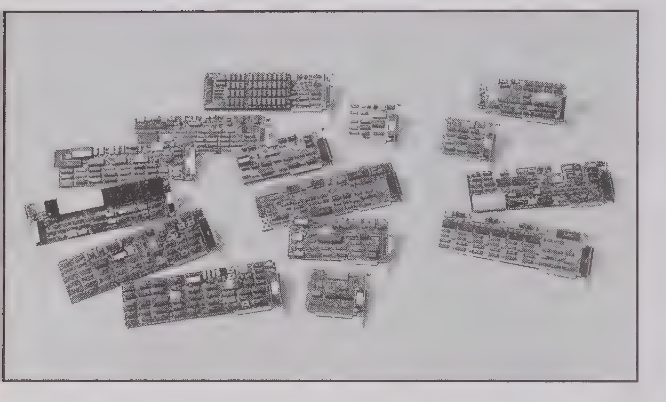
Data Acquisition & Control Accessory Products

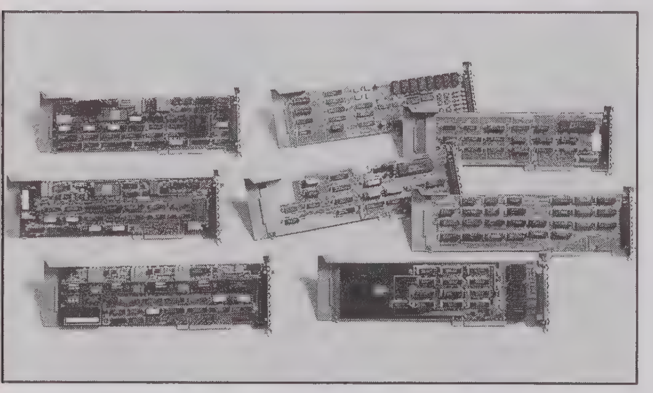
- Expansion Multiplexer Boards
- Universal Screw Terminal Board
- 4-Channel Sample/Hold Box
- Resistance Measurement Board
- 24-Channel DPDT Relay Output Board
- Signal Conditioning Modules
- 4-Channel Isolated Input Box
- Solid-State Relay Boxes

Communication Interfaces

High performance IEEE-488 communication boards for the IBM PC/XT/AT, PS/2 and MicroChannel computers. IEEE-488/GPIB interface with Driver Software package. RS-232 and RS-422 serial interfaces for instrumentation, modem, printer and network applications.

Data Acquisition and Control Products



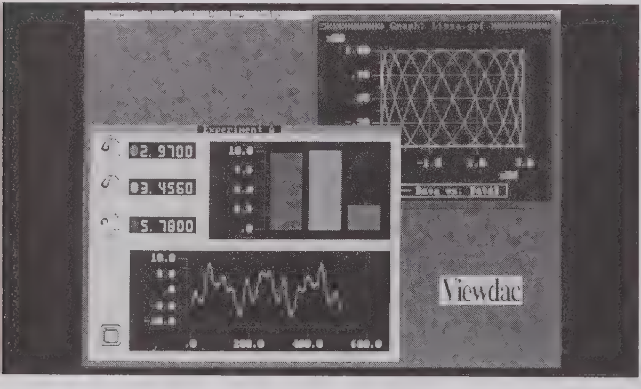


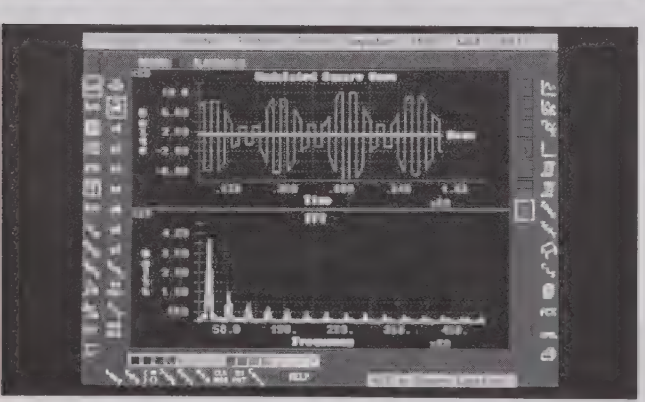
PLUG-IN DATA ACQUISITION BOARDS

Keithley MetraByte offers a wide variety of data acquisition and control plug-in boards to handle a wide range of applications. Data Acquisition boards are offered for IBM PC/XT/AT computers and compatibles, as well as IBM PS/2 and MicroChannel computers. Each Data Acquisition board is designed for easy installation directly into an expansion slot within the PC.

The Data Acquisition product line offers full-featured Analog & Digital I/O boards that provide 8-16 bit resolution, conversion rates up to 1,000,000/second, 16 lines of digital I/O and on-board timers. 12 Bit Analog Output boards, Digital Output boards with up to 96 I/O lines, Multi-channel Counter/Timers, Temperature Monitoring, Motor Controller, Resistance Measurement, Relay Output, plus numerous expansion and accessory products complement this line.

- Data Acquisition I/O Boards
- Analog Output Boards
- Digital I/O Boards
- Counter/Timer Boards
- Motor Controllers
- Expansion Boards and Accessory Products

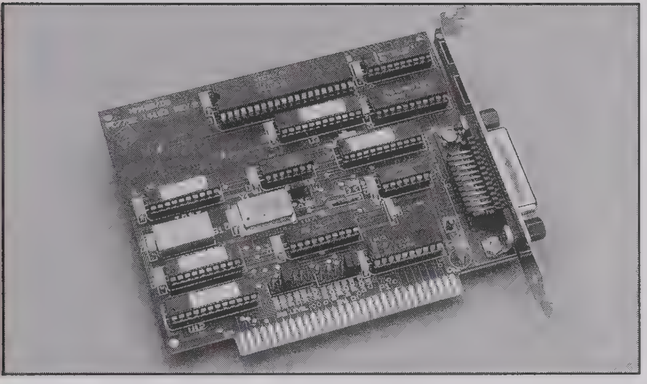


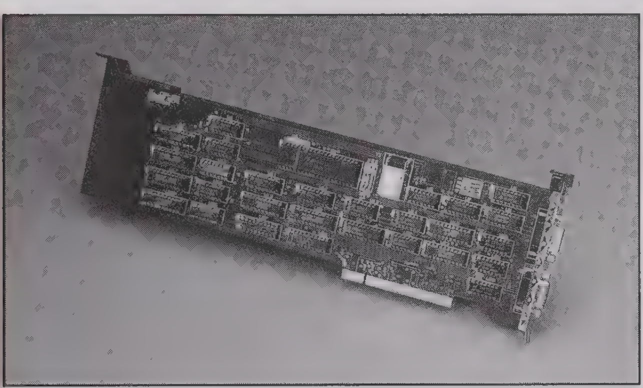


DATA ACQUISITION & ANALYSIS SOFTWARE

- Automated Test, Measurement, and Evaluation
- Process Development and Monitoring
- Integrated Acquisition, Analysis, and Graphics
- Menu-Driven and Fully Programmable Packages

We have the software to meet your needs. Our software gets your application up and running quickly, gives your PC-based workstation more power, and enhances it with features such as real time graphics and sophisticated analysis. Before you even think of committing yourself to programming in C or BASIC, consider a package such as EASYEST, VIEWDAC or Labtech Notebook.

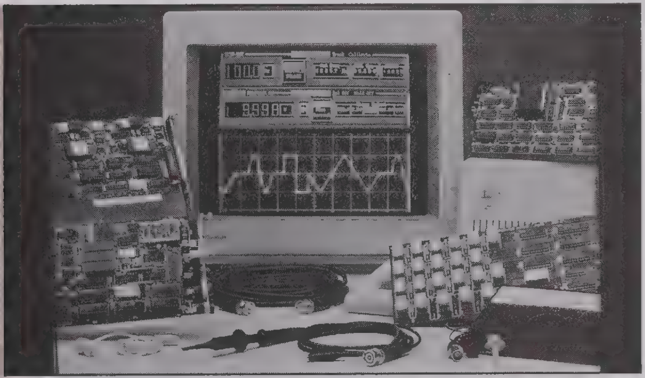


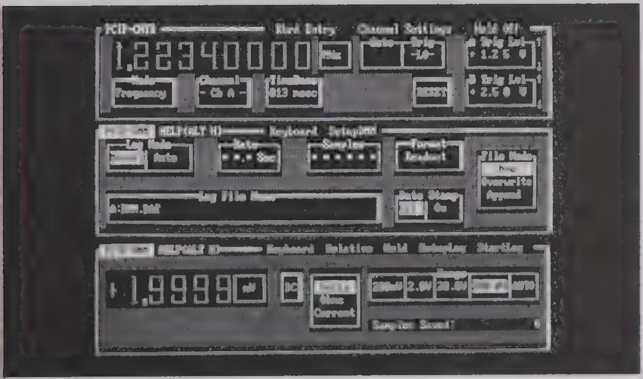


COMMUNICATION INTERFACES FOR IEEE-488, RS-232/RS-422 & RS-485

- IEEE-488, RS-232/RS-422 & RS-485 interfaces for IBM PC/XT/AT and PS/2 Computers
- New Industry Standard IEEE-488 Interface
- Compatible with most GPIB software including Keithley Asyst
- New RS-232 to IEEE-488 Converter

These products include interface boards and software for IEEE-488, RS-232, RS-422 and RS-485, for both the IBM PC/XT/AT and PS/2 computers. A variety of solutions are offered to meet your needs, whether speed, ease of programming or compatibility with application packages is required. These products are designed for use in instrument test systems, printer and plotter interface or automated laboratory setups.




PCIP-CNTR
Hard Entry
Channel Settings
Hold Off
1.2234000000
Frequency
- Ch A -
813 nsec
RESET
+ 1.25 V
+ 2.50 V
HELP(ALT H)
Keyboard
SetupDMM
Auto
Readout
Overwrite
Append
On
1.9999
DC
Current
2.0V
20.0V
AUTO
Samples Saved:

PERSONAL COMPUTER INSTRUMENTATION PRODUCTS

- Full line including: DMM, Counter, Scope, Waveform Generator, Power Supply, Digital Logic Analyzer
- Front Panel Pop-Ups on the Computer's Screen
- Program from Virtually any Language
- Simple English Commands, no GPIB Programming
- Cost Effective Alternative to Instrument Systems

The Personal Computer Instrumentation Products (PCIP) family delivers the same features, functions and performance as bench top, or rack mounted instruments. However, the PCIP instruments plug directly into a powerful measurement system (your PC), at a fraction of the cost of IEEE-488 solutions. The PCIP products can be operated from the computer's screen using front panel pop-ups or simple English commands eliminating confusing GPIB programming tasks.

Measurement & Control Systems

- **Precision**
- **Versatility**
- **Value**

IEEE-488

[illegible]

For more information or help in configuring your Measurement & Control System, contact:

Keithley DAC
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400
Fax: (216) 349-4569

Call or write for Keithley's full catalog of PC-based data acquisition products.

Keithley's Modular Instrumentation

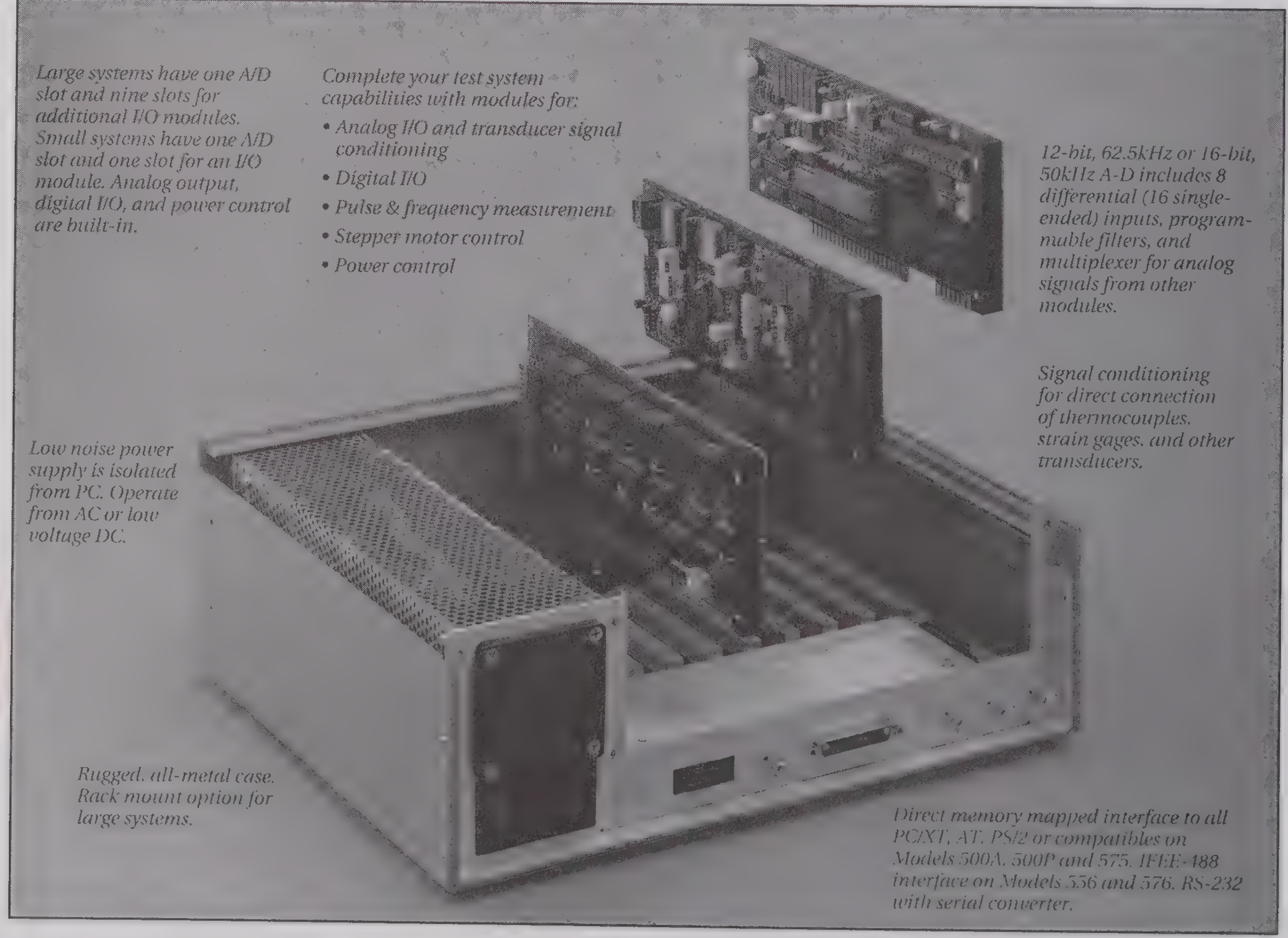
Keithley's Series 500 Data Acquisition & Control Systems are precision instruments offering a high degree of measurement performance, combined with flexibility for a wide range of applications. These systems accurately measure such physical phenomena as voltage, temperature, and strain. They can also control voltages, currents, digital circuitry, and stepper motors.

Series 500 Measurement and Control Systems are ideal for acquiring data from multiple channels, for conditioning signals from specialized transducers, and for performing output or interactive control functions. These systems interface to a variety of computers through an IEEE-488 interface, or to the PC and PS/2 family of computers via a high speed memory-mapped link.

Series 500 systems use an external chassis which accepts plug-in measurement, conditioning, and source modules. The module library fully supports analog input and output, digital I/O, and special functions such as motion or power control. Signal conditioning modules are available for thermocouple, strain gage, LVDT, current loop, and other transducers. This approach provides high quality measurements, with systems that can be easily configured for a particular application. The external chassis also makes it easy to migrate from one computer platform to another (e.g., AT to PS/2).

A wide variety of software is available for Series 500 systems. Standard Keithley DAC packages support real time acquisition in BASIC, C, PASCAL, or FORTRAN. A foreground/background scheme performs critical measurements without time skew. Data can be graphed or easily moved to another package for more detailed analysis. The ASYST family of software provides both data acquisition and analysis for DAC systems. Other popular packages, such as Labtech Notebook, are also compatible with Keithley hardware.

Series 500 accessories help tailor the system to specific applications. These include interfaces to the computers, external signal conditioning and isolation systems, and graphics accelerators.



Large systems have one A/D slot and nine slots for additional I/O modules. Small systems have one A/D slot and one slot for an I/O module. Analog output, digital I/O, and power control are built-in.

Complete your test system capabilities with modules for:

- *Analog I/O and transducer signal conditioning*
- *Digital I/O*
- *Pulse & frequency measurement*
- *Stepper motor control*
- *Power control*

12-bit, 62.5kHz or 16-bit, 50kHz A-D includes 8 differential (16 single-ended) inputs, programmable filters, and multiplexer for analog signals from other modules.

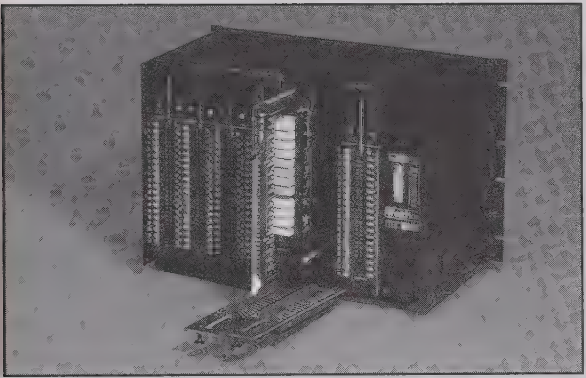
Signal conditioning for direct connection of thermocouples, strain gages, and other transducers.

Low noise power supply is isolated from PC. Operate from AC or low voltage DC.

Rugged, all-metal case. Rack mount option for large systems.

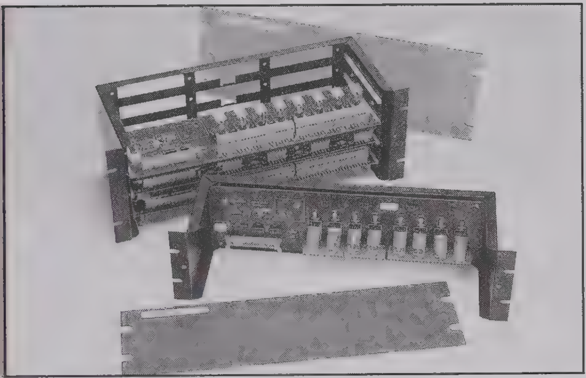
Direct memory mapped interface to all PC/XT, AT, PS/2 or compatibles on Models 500A, 500P and 575. IEEE-488 interface on Models 556 and 576. RS-232 with serial converter.

Industrial I/O Solutions



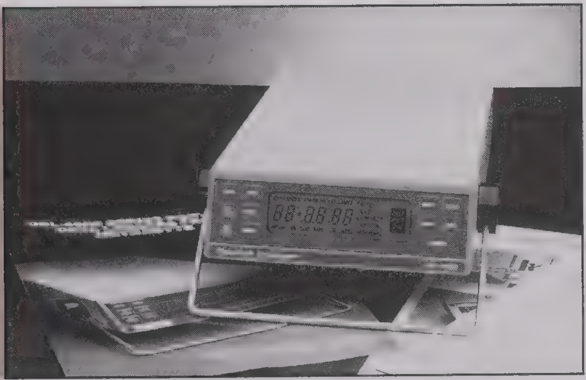
Workhorse

The Workhorse is a 19" rack mount system that allows the user to mix and match plug-in I/O modules to fit a particular application. Modules are available for sensor input, analog output, and digital I/O sensing and control. Connections are made via screw terminal panels that swing down for card removal/insertion without disturbing field wiring. A self-contained unit includes I/O function cards, power supply and computer interface card. Cards are available for RS-232, RS-422, RS-485 and IEEE-488 as well as a high speed proprietary bus. This last option requires a PC or compatible and special expansion driver card. The system is rated for full performance from 0°–60°C. The Workhorse may be mounted in 19" standard RETMA racks, in NEMA enclosures, or wall mounted. Multiple chassis can be networked together.



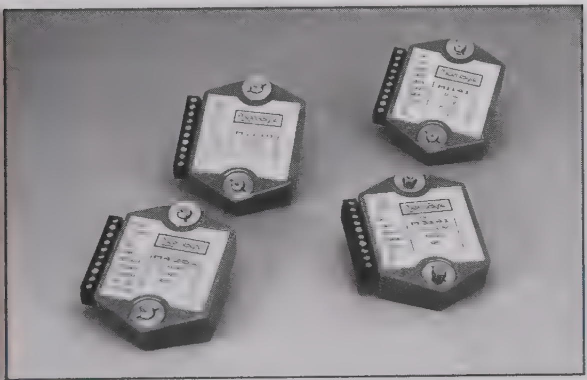
MetraBus

The MetraBus is a low cost, highly adaptable alternative to more rigid, dedicated systems, and is the ideal choice for integration into custom system designs. A broad selection of analog, sensor, and digital I/O functions are available, and may be interfaced through the PC bus, Serial RS232/422/485, or used with a MetraBus local controller for remote applications. All I/O connections are made via board mounted connectors, and all MetraBus cards are linked through ribbon cable. MetraBus is supported by third-party software packages. For those with custom programming needs, driver I/O routines are included, and are supported by MBC-BASIC.



Data Loggers

The DDL Series of data loggers consist of a family of rugged data gathering products and accessories which can operate in environments or situations where a PC may be impractical. The data loggers are stand-alone devices that interface directly to thermocouples or either voltage or current output (4-20 mA) devices. Formatted data is then available at the RS-232C port at a user selected logging interval. Data can be immediately viewed, printed, or stored in the data buffer (thus freeing up the PC). The resultant data may then be processed by software for analysis or charting.



M-1000 Serial Signal Conditioner Modules

The M-1000 Series of modules accept inputs from a variety of process and sensor signals, and convert the data into serial compatible levels for transmission via standard RS-232C/485 protocols. Each module may be programmed for function conversion, limit setting/alarms, and interface parameters, all stored in non-volatile RAM. Multi-drop capability allows up to 124 addressable modules to share a single serial bus, and since all modules in this family are program compatible, a variety of units may be mixed to fit the needs of the particular application.

Data Acquisition & Control Applications

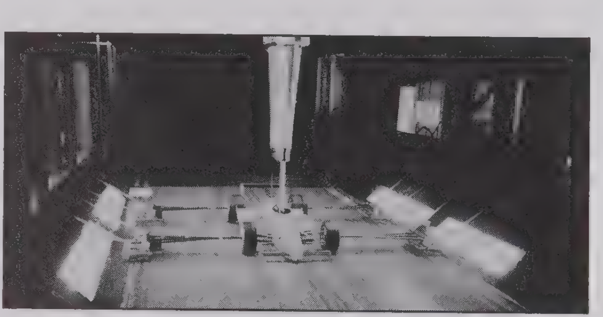
Keithley MetraByte/Asyst/DAC products are used in tens of thousands of applications worldwide. We offer you a few examples of real applications, but we are not suggesting that you're limited to these or related applications. Actually, you may only be limited by your imagination or creativity.

As you see from these examples, we have provided measurement & control solutions for: Wind Tunnel Research, Pulmonary Function Testing, A Laser Marking System, Automated Quality Control, A Battery Test System, and Automated Fault Testing.

Other application solutions can be found in the Keithley/MetraByte/Asyst/DAC handbook. They include: Electron Beam Welding, Photovoltaic Solar Cell Characterization System, Satellite Thrust Engine Test System, Standby Generator Monitor, and many more.

If you need assistance with your application, please call our Technical Support Engineering Department at (508) 880-3000. Our engineers have both the hardware and software expertise to help you select the right products or solve your most difficult problem.

Data Acquisition for Wind Tunnel Research



A low-speed wind tunnel was developed for aerodynamic research on a variety of models including high lift airfoils, propellers, vehicles, and race cars. To provide fully automated testing capability, a PC based data acquisition and control system was developed for the facility to control the tunnel test conditions and also acquire, analyze, and present the experimental data.

A Series 500A data acquisition and control system is used for both test condition control and acquisition of test data. The test condition control system consists of several pressure and temperature transducers, fan speed tachometer, fan speed control potentiometer as well as a tachometer and speed control for a moving ground belt (required for accurate simulation of wheeled vehicles). The tachometer outputs are monitored by digital I/O ports in the Series 500A. The speed control potentiometers are operated by stepper motors controlled by the 500A. The stepper motor/potentiometer is an effective technique for controlling the 1200 HP motor needed to generate airspeeds up to 165 feet per second (approx. 112 mph).

Experimental data sensors vary depending on the application. A typical application such as a race car involves multiple pressure transducers, strain gage balances and often a stepper motor to control the position of the model in the tunnel. To provide a single environment for data acquisition, facility speed control, data reduction, and data presentation, Asyst software is utilized.

CUSTOMER: Department of Aeronautics and Astronautics, Southampton University.

HARDWARE:

Series 500A-PS2		**Test Control**
AMM2		2 Pressure Transducers
DIO1A	*Connected*	1 Temperature Transducer
AIM7	*To:*	2 Tachometers
STEP1		2 Step./Mot. Potentiometers
STEP2		
AIM8		**Experimental Data**
		Multiple Pressure Transducers
		Multiple Strain Gages
		Stepper Motor

SOFTWARE: ASYST.

COMPUTER: IBM PS/2 Model 80.

Pulmonary Function Testing

Pulmonary function testing for pediatric and infant care, research and clinical applications are performed by a PC-based system. Analog inputs from a variety of sensors and conditioners are digitized and analyzed via a data acquisition workstation.

Inputs include 0-5V signals from pneumatic air flow sensors, pressure transducers, a gas analyzer, and oxygen content, heart rate, and blood pressure analyzers.

Up to 10 analog inputs and 1 digital input (for start/stop of system) are typically connected to the system. In most applications only 3 analog inputs are monitored at one time and typically 2 are plotted in real time, usually in a X-Y plot and with some calculations performed prior to plotting the screen. Three digital outputs are used for control of various valves used in the test.

A speed of 100 samples/second on each of 2 channels including calculation, real time display and storage to RAM are achieved. Much higher rates of acquisition and display are possible but only if displayed as Y vs. t and without calculation.

HARDWARE: Model 575 connects to outputs of various sensors/analyzers.

SOFTWARE: Microsoft QuickBASIC, Keithley Quick500.

COMPUTER: 386/16MHz PC with a coprocessor.

PC-Based Control of Laser Marking System

A company manufactures a line of laser printers that are used for printing labels and also for marking directly on various parts and components. The printer systems all use an embedded PC/AT equivalent as the system process controller. Often nonstandard requirements arise for additional monitoring of laser power level and/or control of parts of device handlers. A DASCON-1 A/D board is used to monitor the laser power levels. The digital I/O of the board is used to actuate relays to control power levels of the laser and to control the handler. As needed, the DASCON-1 also includes the optional 1 or 2 channel D/A when analog control of the positioning handlers are required.

CUSTOMER: A West Coast manufacturer of laser marking systems.

HARDWARE: DASCON-1 with 2-DAC 12, and 2 IAM63 amplifiers.

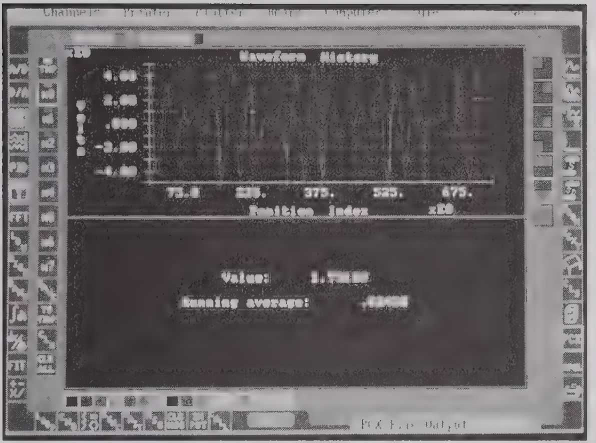
SOFTWARE: Program written in "C" using MetraByte drivers.

COMPUTER: Embedded AT-286.

Automated Quality Control with a PC-Based System

A manufacturer of transmissions uses EASYEST software, a DAS-8 and four of the MB signal conditioning modules to do spot checking for quality control.

A randomly selected transmission from each production batch is run for a four hour period at the equivalent speed of 65 mph. Temperature points at four different locations are sampled once per minute, compared to maximum permissible values, and logged to disk. The system also monitors the vibration, taking 50 milliseconds of data every minute at a rate of 5kHz (allowing detection of frequencies up to 2.5kHz). Vibration waveforms are acquired and plotted then an FFT is performed on them to determine the frequency spectrum. This spectrum is plotted and the maximum amplitude automatically determined by the software. This amplitude is compared to the standard tolerance range. If any of the parameters, maximum amplitude, or temperature at any point, exceeds the norms, then a message is displayed and a digital bit raised which shuts down the engine. All anomalous frequency spectra are also stored to disk.



At the end of the four hour run, the screen displays messages which summarize the test results.

CUSTOMER: A Midwest transmission manufacturer.

HARDWARE: DAS-8 connected to:

- 4 MB Signal Conditioning Modules
- 1 Piezoelectric Vibration Transducer
- 1 Digital Relay

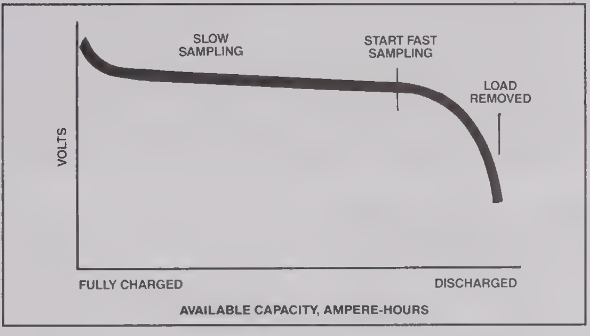
SOFTWARE: EASYEST

COMPUTER: 16 MHz AT Compatible

Battery Test System

A component engineering department needed to measure in detail the discharge curves of a sample set of batteries over relatively long times.

The batteries being tested have a relatively constant discharge rate during the initial 90% of useful life. Measurements during this time require relatively slow acquisition rates. When the discharge rate approaches the knee of the curve, the voltage drops at a considerably faster rate and measurements must be made more rapidly during this phase. Furthermore, it is necessary to remove the load from the battery when voltage reaches a certain minimum level to prevent cell damage. Because this battery test was part of a multiple system test station, it was desired that all the decision making, reading rate changes, and load control would be done by the test instrument rather than the computer controlling the test station.



A Model 576, High Speed Data Logger was used to meet these requirements. Connected to the controlling PC via the IEEE-488 bus, all read rates, trigger conditions, and thresholds are downloaded to the 576's program memory. Upon completion of the test, results are uploaded to the PC for report generation.

CUSTOMER: A Midwest manufacturer of electronics assemblies.

HARDWARE: 576-1, MBC-488 Interface connected to:

- Batteries under test
- Relays to Control Load
- Other GPIB Instruments

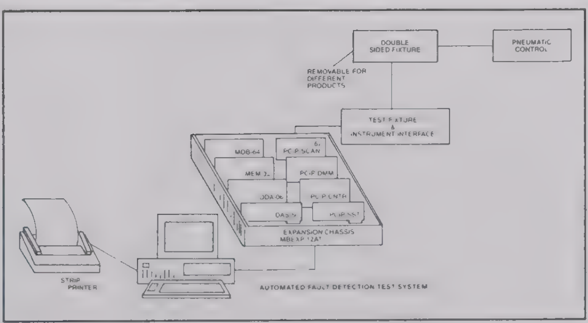
SOFTWARE: Microsoft QuickBASIC and routines loaded into the 576.

COMPUTER: 286 PC.

Automated Fault Detection Test System

This PC based Automatic Test and Control system allows the user accuracy and ease of use, while minimizing operator intervention. Several virtual instruments (PCIP-SCAN/DMM/CNTR/SST) provide a means to generate waveforms, multiplex signals, and measure parameters for the Detection Systems Corp. application.

Custom routines written in high level C language generate a screen display enabling different functional tests to be chosen, as well as outputting pass/fail codes forwarded to a strip printer.


DOUBLE SIDED FIXTURE
PNEUMATIC CONTROL
REMOVABLE FOR DIFFERENT PRODUCTS
TEST FIXTURE & INSTRUMENT INTERFACE
MDB-64
(6) PCIP-SCAN
MEM-32
PCIP-DMM
DDA-06
PCIP-CNTR
DAS-50
PCIP-SST
EXPANSION CHASSIS MBEXP-12AT
STRIP PRINTER
AUTOMATED FAULT DETECTION TEST SYSTEM

The DAS-50 performs control functions, peak-to-peak digital filtering and other functions for the PCIP-DMM. The design of this set up operates in a similar manner to a GENRAD interface. However, it provides flexibility for design functional testing, to simulate end user aspects.

CUSTOMER: Detection Systems.

SOFTWARE: Proprietary program written in C language.

COMPUTER: IBM 286.

HARDWARE:

Test:	PCIP-SCAN (6 units) PCIP-DMM PCIP-SST PCIP-CNTR
Control:	MDB-64

Process Measurement Systems

- DEC VAX controller
- GKS graphics support
- Crosspoint matrix architecture
- 4-wire full Kelvin connections—source, measure, guard, ground
- Up to 4 test stations on the S450
- 1 test station on the S425
- Up to 256 pins/ instrument terminals
- Single instrument source and measure provides both voltage and current functions
- Differential source/ measure capability
- Options:
  - Capacitance and conductance meters
  - Electrometer with 10fA resolution
  - Microvoltmeter with 100nV resolution
  - Frequency counter
  - Pulse generator
  - 10A pulsed voltage source
  - 2A pulsed voltage source

For complete information on Keithley Systems Division products, contact:

Systems Division
Keithley Instruments, Inc.
30500 Bainbridge Road
Cleveland, Ohio 44139-2216
(216) 248-0400
Fax: (216) 248-6806

KEITHLEY SYSTEMS

The S400 Series of DC Parametric Test Systems, from Keithley Systems Division, provides a range of solutions from R&D to high volume production. These systems can be configured with a variety of hardware, software, and computers to satisfy individual requirements.

The **YieldMax S450** is the industry standard in production parametric test. It combines Keithley measurement technology with the power of a DEC MicroVAX computer. Its flexible hardware and wide range of options allow the S450 to fulfill diverse requirements. The S450 provides the highest available throughput for data acquisition, analysis, and report generation.

The S450 is the ideal production test system. The instrumentation has been optimized for multiple test station operation. The power of the 32-bit VAX allows access to all system resources with minimal performance impact. Communication between the VAX and the instruments is over a dedicated DMA link for high speed. The multi-user, multi-tasking capabilities of the VMS operating environment allow several tasks, such as program development, testing, and data analysis, to be carried out at the same time. The graphics software, based on the Graphics Kernel System (GKS), permits high device independence and supports a variety of terminals and hard copy devices. An available Ethernet interface allows easy connection to CIM environments.

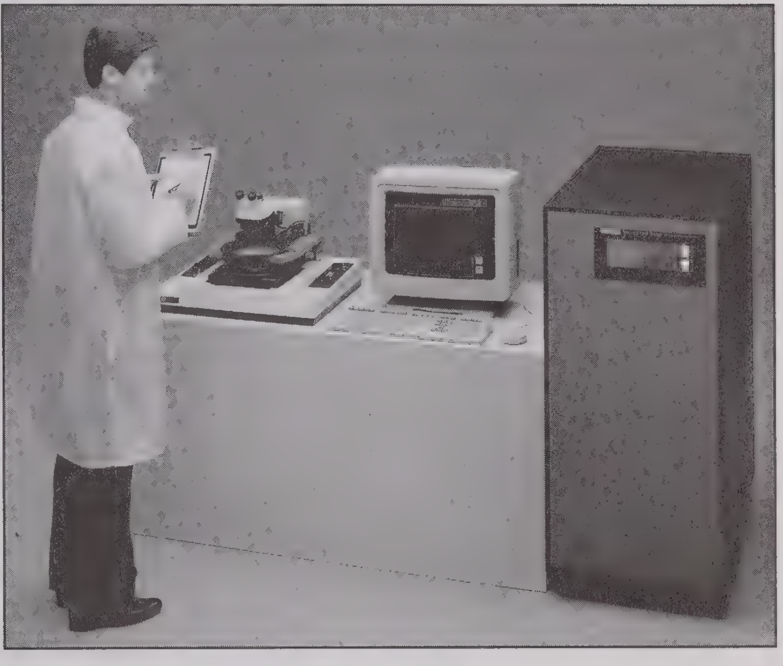
The **YieldStar S425** combines the measurement technology proven in S450 installations worldwide with the capabilities of the VAX workstations. This single test station design is suitable for light production, development and research.

The S425 is configured as a parametric test workstation. A VAXstation 3100 provides the 32-bit power of a VAX in a desktop package at an affordable price; for multi-user applications the MicroVAX computers are also available. The standard VMS operating environment, as well as the new VAX Window Services (VWS) windowing environment for the VAXstations, allows a single user to execute tasks such as testing and data analysis simultaneously in different windows. This system also uses GKS. The built-in ThinWIRE Ethernet interface allows easy connection into networks.

The S400 Series incorporates the most advanced measurement technology available. Based on the VME bus, it uses a Motorola 68020 microprocessor for all direct instrument control, off-loading much of the measurement overhead from the VAX. Voltage and current force/measure functions are provided by the VIMS, a single instrument capable of differential, range-independent force and measure.

Process Measurement Systems

S400 Series



This flexibility allows simplified test configurations and reduces switching overhead. Optional capacitance/conductance meters are available which operate at 100kHz or 1MHz.

Signals between the instruments and the device under test are switched through a fully guarded, full Kelvin crosspoint matrix. This allows flexibility and accuracy without cumbersome test heads. The matrix incorporates six pathways, two of which are optimized for low current and capacitance measurements.

The S450/S425 are integral members of the Keithley parametric test system family and share a common software environment. They provide a migration path from older S300 and S350 systems. If you are an existing S300/S350 user, a compatibility mode of operation allows you to use your existing test programs with minor modifications. The S425 and S450 are fully software compatible and allow you to easily migrate software—for example, as a product moves from pilot to full production, or as a process makes the transition from development to manufacturing.

Software tools make the system easy to use. On systems with a capacitance meter, a C-V measurement and analysis program acquires MOS C-V curves and extracts common device parameters. An optional interactive I-V "curve tracer" program allows easy investigation of device characteristics. The EasyTest package provides a menu-driven graphical interface. In addition to allowing easy access to system functions, it provides a powerful FORTRAN program generator.

The optional KIDATA package includes the Data Manager II database which features fast data logging to improve throughput. A report generator provides tabular listings of test results stored in the database. The YieldStat data analysis package allows the common types of graphical analysis, histogram, trend, scatter, box plot, and wafer maps to be performed interactively or in batch mode, and features relational data extraction.

The VAX can support many standard third party packages for more rigorous statistical analysis and device modeling or parameter extraction.

For complete information on Keithley Systems Division products, contact:

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Keithley Instruments, Inc.
30500 Bainbridge Road
Cleveland, Ohio 44139-2216
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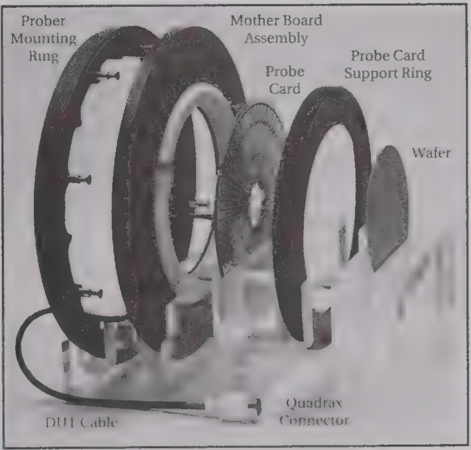
Fax: (216) 248-6806

Probe Card Adapter

PCA

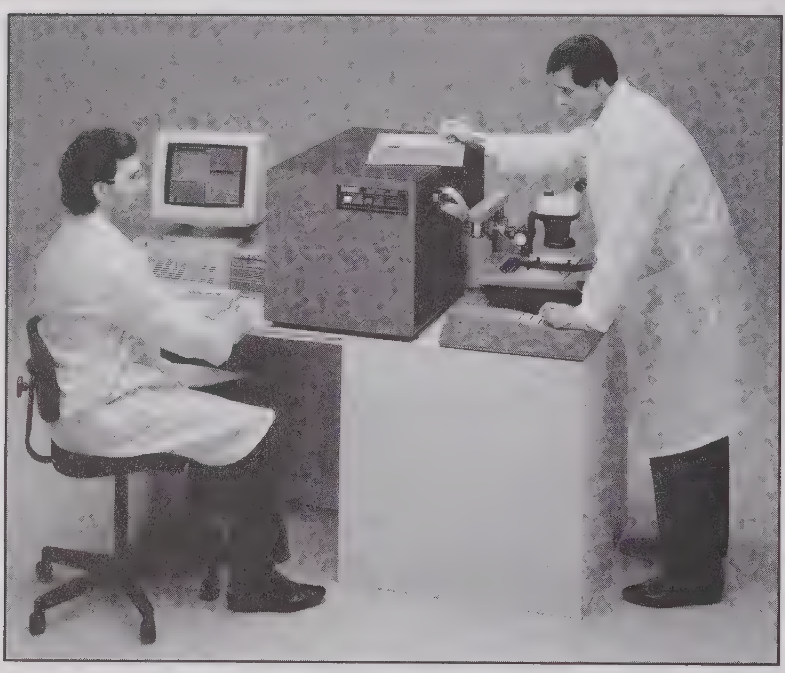
The 9139 Probe Card Adapter (PCA) facilitates the interface between the test station cables and the probe card used to contact the device under test. The PCA is optimized for the requirements normally associated with parametric testers, and is compatible with all Keithley test systems.

The PCA works with a variety of probers incorporating a "ring mount" probe carrier. The prober ring which fits in the ring mount is the major hardware interface between the prober and the PCA. The mother board assembly attached to this ring provides the interface between the DUT cables and the probe card. The fully guarded, full Kelvin probe card extends the separate source, measure, and guard paths to the pad to which the probe blade is soldered.



- **Pin-to-pin leakage**
  Guarded: 0.1pA/V
- **Pin-to-pin capacitance**
  Guard grounded: 0.5pF
- **Maximum pins: 64**
- **Probers supported:**
  Electroglas 1034X, 2001X
  Rucker & Kolls 680, 681
  KLA 1007
  TSK 6000

S900 YieldStation Process Monitor Workstation



- **20MHz 386 computer, VGA monitor**
- **Tree matrix architecture**
- **2 isolated paths for low current and capacitance measurements**
- **Single test station up to 64 pins**
- **3-wire full Kelvin, fully guarded**
- **Single instrument force and measure provides both voltage and current functions**
- **Voltage force and measure from 30μV to 100V**
- **Current force and measure from 60pA to 1.5A**
- **Optional capacitance meter with 0.3fF resolution**
- **Optional picoammeter with 0.6fA resolution**

For complete information on Keithley Systems Division products, contact:

Systems Division
Keithley Instruments, Inc.
30500 Bainbridge Road
Cleveland, Ohio 44139-2216
(216) 248-0400
Fax: (216) 248-6806

The YieldStation S900 is a personalized solution for device characterization or process problem detection in a semiconductor testing environment. The S900 is targeted at new start-ups, pilot lines or anyone needing a fast, flexible, PC based parametric test system.

Unlike larger, more expensive tools, the S900 maximizes the speed and efficiency of the test and measurement event. A powerful and flexible set of instrumentation, a low noise, hierarchical tree matrix and a personal computer provide you with a sensitive tool that can be custom tailored to solve your application-specific needs. The S900 augments the capabilities of the S400 series by providing a low cost personalized tester. Whether your application is MOS, Bipolar, or GaAs, wafer or discrete, the S900 provides the most cost effective solution for acquiring parametric data.

The YieldStation is as compact and easy to use as a stand-alone engineering or production workstation. Its testing capabilities can be easily expanded by networking duplicate sets of hardware and/or integration with other Keithley products. Modular design and self-configuring software allow you to easily increase or enhance test hardware configurations by simply plugging in cards to add more matrix pins (up to 64 per system) or Force/Measure Units (up to 5 per system). No re-wiring or software modifications are necessary.

The S900 is the fastest tester on the market. This performance has been achieved without sacrificing accuracy or repeatability. Accuracy and repeatability are typically better than 0.05% of scale. The result is that you can quickly acquire data you can trust, to make quality decisions about your process.

The YieldStation provides an easy to use yet powerful set of tools to configure parametric test instrumentation sequences. By adding support for instrument control commands to industry standard PC software, we have made testing simple. Microsoft® QuickBASIC is supplied with the system as the standard environment for test program development. This language incorporates the best features of compiled and interpreted programming languages. It also includes an on-line program debugger that helps bring new test routines up quickly. Other languages including Microsoft® Pascal, FORTRAN and C can be provided as options. A library of test subroutines is also supplied as part of the standard system software. This library includes many of the common measurements for resistors, capacitors, diodes, MOSFETs and BJTs. Sources code is provided to customize these routines.

In characterization, development, and failure analysis, the ability to view graphic displays of device characteristics is often crucial. The YieldStation S900 can quickly produce I-V and C-V plots with the optional Interrogator curve tracer package. This program, which runs under the Microsoft® Windows environment, features easy to use pull-down menus that allow you to configure and execute many common device measurements and then examine the collected data on a graphic display. The flexibility provided by the combination of Interrogator and Windows allows multiple characteristics of one or more devices to be examined simultaneously.

Because of its simplicity, our YieldStation S900 customers are often testing their devices the same day the system is installed. The S900 is very reliable, with a MTBF in excess of 2000 hours, and comes with a 90 day full service warranty and a one year parts exchange policy. Keithley offers a number of programs for maintenance, extended coverage and spares. Finally, there are Keithley's worldwide Technical Support offices to bring you real time assistance.

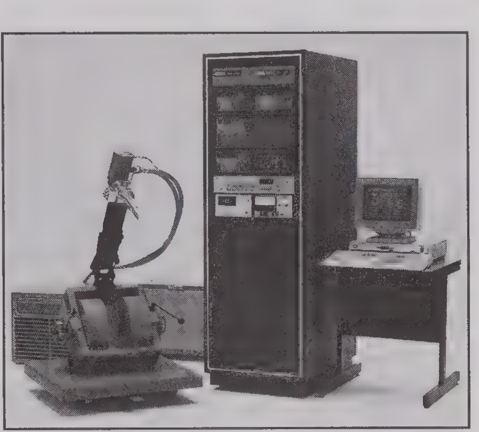
The YieldStation S900 is suitable for a variety of applications in different areas of technology. It is widely accepted among GaAs device manufacturers because of its speed and stability which make it suitable for DC characterization of discrete, high frequency devices. In MOS development and characterization the speed and low current performance of the S900 make it the logical choice where a personalized solution is required. The flexibility of the S900 allows it to be easily configured for use wherever the primary need is to collect accurate data quickly.

GaAs Hall Effect Test System

S110

The Keithley System S110 provides reliable, accurate performance without the time, expense, and frustration of assembling a Hall test system piecemeal. The S110 is fully integrated and tested by Keithley; thus, users can concentrate on testing rather than on hardware and software development.

The standard system includes all the hardware to perform room temperature Hall Effect measurements except the magnet. The system contains a Model 220 Current Source and a Model 617 Electrometer to force and verify the sample current. A Model 196 System DMM measures the voltage developed across the sample. Switching is accomplished through a Model 706 Scanner which controls the Quad Buffer Amplifier. This amplifier incorporates a low leakage, low offset voltage switching matrix with four high input impedance electrometer amplifiers with input impedance of more than $10^{14}\Omega$.



The S110 includes software to automatically measure and calculate resistivity, Hall coefficient, carrier concentration and carrier mobility from the measurements. Configurations for van der Pauw or six contact bar type samples can be selected. All measurements and calculations adhere to ASTM F76 standards. The software uses a convenient menu driven interface to collect sample and set-up information. Results can be stored, printed or graphed vs. temperature or magnetic field. Software is provided for system diagnostics. A test box can be used as a dummy sample to verify system operation.

Options available for the S110 include electromagnets and cryogenic systems.

- **Measures from 10^{-2} to $>10^{10}\Omega$**
- **Controlled by IBM-PC**
- **Software written in Microsoft QuickBASIC**
- **Optional cryosystem and electromagnet**
- **Software for plotting vs. temperature and magnetic field**

Semiconductor Test System

iPTest

Keithley's Systems Division is the exclusive U.S. sales and support representative for iPTest Ltd., a manufacturer of state-of-the-art semiconductor test systems. The combination of Keithley's qualified sales and technical support staff with the experienced professionals of iPTest provides an unparalleled solution to the testing needs of discrete and smart power semiconductor manufacturers.

iPTest systems test a wide range of semiconductor components with analog, logic and stress testing capability. In addition to testing standard components, the iPTest system is designed to accommodate a variety of high voltage, high current and high power testing requirements. It incorporates a number of features to allow testing of a wide variety of components. The indexed parallel architecture allows for the highest possible throughput. The iPTest can be software configured according to the functional requirements of the test to be performed. A powerful Pascal-based menu-driven test plan generator provides interactive testing.

- Up to 100A at 30V pulsed
- Up to 3000V at 1A pulsed
- Up to 1000W DC

- For testing:
  Power transistors
  Smart power to 32 pins
  Automotive ICs
  MOSFET transistors
  Bipolar transistors
  Arrays to 24 pins
  SCRs and triacs
  Voltage regulators
  Surge suppressors
  Diodes and rectifiers
  Zener diodes

KEITHLEY RADIATION MEASUREMENTS

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To place your order, or to receive a complete catalog or other detailed information, contact:

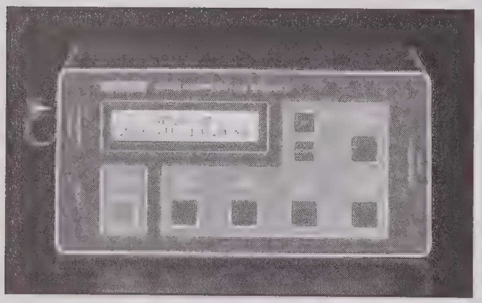
Radiation Measurements Division
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400 or (216) 248-0818
Fax: (216) 349-2307
Telex: 205124

OUR CURRENT PRODUCTS

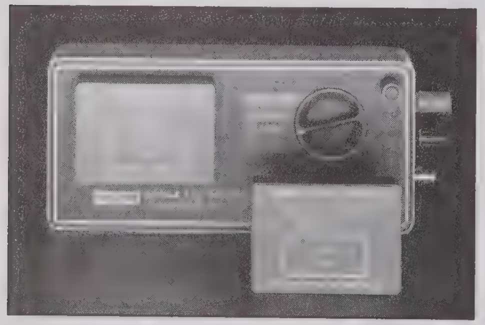
The Radiation Measurements Division offers a line of precision dosimeters, ion chambers, log picoammeters, exposure controls, X-ray quality assurance and service instruments, and radiation survey and monitoring equipment.

FIELD SERVICE/CALIBRATION

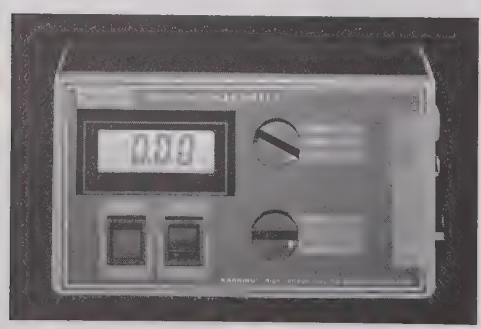
The **TRIAD Dosimeter (Model 35050A)** is our latest development for X-ray field service. It is a general purpose, micro processor based, state-of-the-art, full function dosimeter with simplified operator controls and a direct readout. The dosimeter also provides a direct readout for the Keithley Model 35080 and 35080A non-invasive kVp Divider. The **Model 35080A** is an enhanced version of the Model 35080 consisting of a single filter pack for measuring kV over the diagnostic X-ray range from 50 to 150 kV, instead of the previously supplied set of 3 filter packs to cover this same range. A recent addition to our family of X-ray service instrumentation includes our **Model 35035** mA/mAs meter.



Model 35050A Triad Dosimeter



Model 35080A Non-Invasive kVp Divider



Model 35035 mA/mAs Meter

These instruments constitute our **X-ray Field Service Kit (Model 10500AM)**. The kit is available in several versions, and can be used for calibration, compliance testing, troubleshooting, installation and set-up of equipment, preventative maintenance, quality assurance measurements and JCAH accreditation. It performs measurements on all modalities such as mammography, cine, dental, radiography, fluoroscopy, CT and image intensifiers. Some major features of the Model 35050A Dosimeter included in the kit include automatic reset, autoranging, offset and drift compensation and power down. It operates from 6-AA batteries and has an electronic bias supply (300V). The direct readout in user selected units includes R, Sv, Gy, A, C, /sec, /min, /hr, /frame and can be pressure and temperature corrected. The unit will accommodate any BNC triaxial ion chamber with known calibration factor. High sensitivity for image intensifier measurements and measurements of kVp, dose, and exposure time with a single exposure (using the Model 35080A or 35080 kVp dosimeter). The RS-232 interface provides remote operation, waveform capture, digital calibration, customize display units, ion chambers and filter packs. The unit is also self-checking.

Model 10500AM Triad X-ray Service Kit

The Model 35080A makes the easiest, quickest, and most accurate kV tests possible on radiographic, mammographic and fluoroscopic X-ray equipment.

You can check both above- and below-table sources and display the proportional analog voltage signal on a peak read-and-hold DMM, the Model 35050A Dosimeter/kVp Readout, or storage oscilloscope.

The Model 35080A was specifically designed to work with the high-speed, accurate, wide-bandwidth oscilloscopes normally used for repair and calibration of X-ray generators.

When you display the waveform on an oscilloscope you can also measure exposure time for single-phase, three-phase, DC and high-frequency generators.

New and Selected Products

AUTOMATIC EXPOSURE CONTROLS/ REPLACEMENT ION CHAMBER MODULES

With over ten years of experience building phototimers, we added automatic exposure controls (AECs) to our product line. Both Models **75100** (mammographic AEC) and **75200** (radiographic AEC) reduce retakes, minimize patient exposure, and enable high throughput operation of X-ray units by providing consistent film densities. Both units are easy to install and calibrate, and the control board mounts either inside an existing generator panel or in a separate instrument case. A special feature is multiple screen/film compatibility: A PROM provides a digital kV compensation network with up to four screen/film combinations.

The **Model 10909** and **10911** ion chamber modules are direct replacements for General Electric bucky and chest stand units. They are easy to install and connect.

HEALTH PHYSICS

Our **36000-Series Survey Meters** are used in health physics programs in clinical settings such as isotope storage areas and monitoring of brachytherapy patients. These survey meters include the Model 36150 and 36155 (our integrating survey meter with its standard and beta window versions, respectively) and the Model 36350, our integrating survey meter with readout in millisieverts, the International Metric System unit for radiation dose.

Model 36000 Family of Radiation Survey Meters

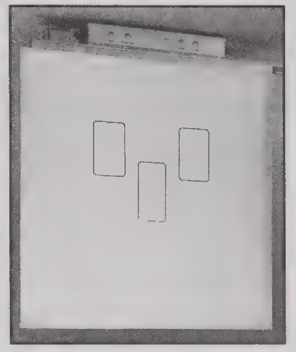
MEDICAL PHYSICS

The newest products in our line of therapy dosimetry products include a Direct Readout to our popular **TRACKER Therapy Beam Evaluator**. This readout allows quick checks of beam constancy, flatness and symmetry. The readout is in constancy or ratiometric units. It is easy to use and can be set up quickly for daily accelerator checks. The interconnect cable is the same as that used for the computer interfaced version of the TRACKER, so that the IBM compatible computer and TRACKER Display are readily interchangeable. The System allows the use of buildup at any ganty angle. The computer interfaced version provides graphs of on going flatness, symmetry, constancy, and energy constancy when using our ENGCON energy constancy enhancement.

MODEL 75200 RADIOGRAPHIC AEC
FIELD SELECT
DENSITY
RESET

Model 75200 Automatic Exposure Control

To our family of precision therapy dosimeters Models 35617EBS and 35614,we have added a new dosimeter, **Model 35614E**. This instrument features direct readout in Grays or roentgens in addition to the usual coulomb and ampere ranges. It operates from a rechargeable battery pack and has an electronic bias supply.

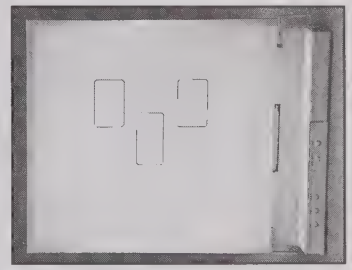


Model 10909 GE Ion Chamber Replacement Module (Table Bucky)

X-RAY QUALITY ASSURANCE

The **DARTT System** is a reasonably-priced radiological test system that runs on IBM-compatible computers. The System takes measurements, performs the necessary calculations, and stores and prints test results in a handy, comprehensive report form.

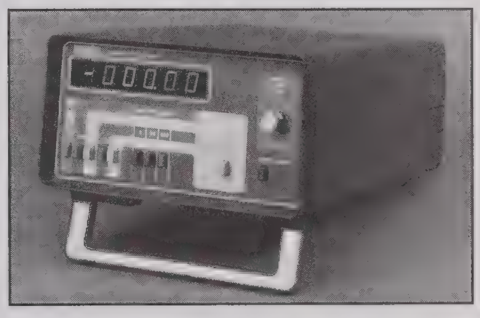
The **Model 35075 Digital kVp Meter** allows safe, accurate measurements of X-ray tube voltage, without disturbing high-voltage cables. An option displays a true kV waveform signal on a storage oscilloscope.



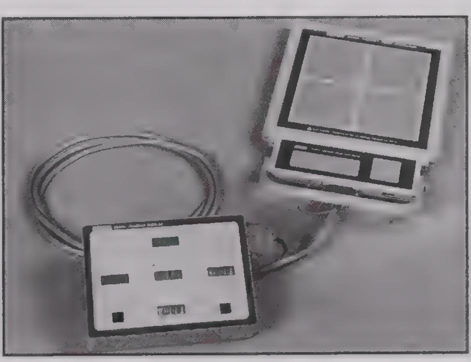
Model 10911 GE Ion Chamber Replacement Module (Chest Stand)

The **Model 35065 Digital Dosimeter** performs quick checks of X-ray machine performance. The energy response range allows excellent mammographic dosimetry as well as typical radiographic measurements.

The **Model 30030 X-ray Timer** provides a fast, efficient means of calibrating or verifying the accuracy of built-in radiographic and therapy system timers. Its typical mammographic measuring range (25–35 kVp, 50–100 mA, depending on beam filtration) allows timing of mammographic X-ray systems.



Model 35614E Direct Reading Therapy Dosimeter



Model 35300/35360 Therapy Beam Evaluation System (TRACKER with Direct Readout)

Glossary 222
U.S. Sales Representatives 228
International Sales Representatives 229
Ordering Information 231
Warranty and Service Information 232

Ordering and Other Information

Glossary

Absolute Accuracy. A measure of the uncertainty of an instrument reading compared to that of a primary standard having absolute traceability to the National Institute of Standards and Technology. It is expressed in ppm. *See also* Rated Accuracy.

Acceptor. An impurity that can make a semiconductor P-type by accepting valence electrons, thereby leaving holes in the valence band. The holes act like carriers with a positive charge.

Accumulation. The region of operation in a MIS capacitor where the majority carriers accumulate near the semiconductor-insulator surface.

Actuation Time. The time between application of the nominal relay coil voltage and the final closure of the relay contacts after the contact bounce interval. Also called *operate time.*

Analog Output. An output that provides an analog signal derived from the digital information within the instrument.

Aperture Jitter. The short-term variation of aperture time.

Aperture Time. The time interval during which an amplifier or measuring instrument acquires a sample of the signal. Also known as the *sample window.*

Autopolarity. The ability of an instrument to measure and display an input of either polarity without switching the input leads.

Autoranging. The ability of an instrument to automatically switch among ranges. The ranges are usually in decade steps.

Autoranging Time. For instruments with autoranging capability, the time interval between application of a step input signal and its display, including the time for determining and changing to the correct range.

Average Responding. A measurement where the displayed value is proportional to the average of the absolute values of all input waveforms within a specified frequency range. It is calibrated in the rms value of a sine wave.

Bandwidth. The range of frequencies that can be switched, conducted, or amplified within certain limits. Under given load conditions, bandwidth is defined by the -3dB (half-power) points.

Bank. A group of relays with a common connection for scanning or multiplexing applications.

Bias Voltage. A voltage applied to a semiconductor to establish a reference level for the operation of the device during testing.

Break-before-make. Disconnecting the present circuit before connecting a new circuit.

Cable Compensation. Correction for the errors caused by the cables that connect the device under test to the meter. The cables (or other connection devices, such as switches and probers) have series resistance and inductance, shunt capacitance, and phase delay, which cause the errors.

Capacitance. In a capacitor or system of conductors and dielectrics, that property which permits the storage of electrically separated charges when potential differences exist between the conductors. Capacitance is related to charge and voltage as follows: $C = Q/V$, where C is the capacitance in farads, Q is the charge in coulombs, and V is the voltage in volts.

Capacitance Non-linearity. A relationship between the actual and measured capacitance across a range that cannot be described with a straight line. The most common source of non-linearity is connection or cable error. *See also* Cable Compensation.

Capacitance Voltage. The relationship (or curve) of capacitance versus voltage for a device. Generally measured on Schottky, P-N, or MIS structures. CV curves are of interest to ascertain device geometry, internal device potentials, and device charges.

Capacitive Displacement Current. The current that flows in a capacitor in response to a voltage change across the capacitor.

Carry Current. The maximum continuous current of closed relay contacts. Most relays are rated higher for carry current than switched current. (Heat is generated by I^2R losses for carry current and I^2R losses plus arcing for switched current.) *See also* Switched Current.

Channel (Semiconductors). The conducting region between a FET source and drain that is controlled by the applied gate voltage. The majority carriers are holes in P-channel FETs and electrons in N-channel FETs.

Channel (Switching). One of several signal paths on a switching card. For scanner or multiplex cards, the channel is used as a switched input in measuring circuits or as a switched output in sourcing circuits. For switch cards, each channels signal paths are independent of other channels. For matrix cards, a channel is established by the actuation of a relay at a row and column crosspoint. *See also* Path.

Channel Isolation. On a switching card, the isolation from signal high and low of one channel to signal high and low of any other channel (or the output on switch or scanner cards). Specified as resistance and capacitance, except for RF cards (decibels and frequency range). *See also* Path Isolation.

Charge Carriers. Holes or electrons that are available in a semiconductor substrate for conduction of electric current.

Coil Resistance. A nominal value of the resistance of a relay coil winding at a specified ambient temperature.

Cold Junction. The junction in a thermocouple circuit that is held at a stable known temperature. Also known as *reference junction.*

Cold Switching. Closing the relay contacts before applying voltage and current and removing voltage and current before opening the contacts. (Contacts do not make or break current.) *See also* Dry Circuit Switching.

Column. As viewed on the schematic of a matrix relay card, the vertical signal lines or a vertical group of relays.

Glossary

COMMON MODE INPUT ISOLATION. On a switching card, the isolation from signal high and low to guard (or shield) for a 3-pole circuit, or from signal high and low to chassis ground for a 2-pole circuit. Specified as resistance and capacitance.

COMMON MODE REJECTION RATIO (CMRR). The ability of an instrument to reject interference from a common voltage at its input terminals with respect to ground. Usually expressed in decibels at a frequency.

COMMON MODE VOLTAGE. A voltage between input low and chassis ground of an instrument.

COMPLIANCE CURRENT. The maximum output current of a constant voltage source. Also known as *current limit.*

COMPLIANCE VOLTAGE. The maximum output voltage of a constant current source. Also known as *voltage limit.*

CONDUCTANCE (G). The reciprocal (1/R) of resistance, usually specified in Siemens (S).

CONTACT BOUNCE. The intermittent and undesired opening of relay contacts during closure, or closing of relay contacts during opening.

CONTACT LIFE. The maximum number of expected closures before failure. Life is dependent on the switched voltage, current, and power. Failure is usually when the contact resistance exceeds an end of life value.

CONTACT OFFSET VOLTAGE. *See* CONTACT POTENTIAL.

CONTACT POTENTIAL. A voltage produced between contact terminals due to the temperature gradient across the relay contacts, and the reed-to-terminal junctions of dissimilar metals. (The temperature gradient is typically caused by the power dissipated by the energized coil.) Also known as *contact offset voltage. See* THERMOELECTRIC VOLTAGE.

CONTACT RATING. The voltage, current, and power capacities of relay contacts under specified environmental conditions. *See* CARRY CURRENT *and* SWITCHED CURRENT.

CONTACT RESISTANCE. For a relay, the resistance in ohms across closed contacts. For a Keithley switching card, also includes the tape resistance and connector terminal resistance. *See also* PATH RESISTANCE.

CONTAMINATION. Generally used to describe the unwanted material that adversely affects the physical, chemical, or electrical characteristics of a semiconductor device.

CONVERSION. A process where a signal is changed from an analog to digital (A-D) representation, or digital to analog (D-A).

CONVERSION TIME. The time required to complete an analog to digital or digital to analog conversion.

CORROSION. An unwanted electrochemical process that affects device (e.g., semiconductor) reliability.

CREST FACTOR. The ratio of the peak value to the root-mean-square (rms) value of a waveform.

CROSSPOINT. The intersecting point of a column and row in a relay matrix. Specified as (column, row) or (row, column). A crosspoint generally consists of one or more poles of Form A (normally open) relay switching.

CROSSTALK. The coupling of a signal from one input to another (or from one channel to another or to the output) by conduction or radiation. Crosstalk is expressed in decibels at a specified load and up to a specific frequency.

DEPLETION. The region of operation in a MIS capacitor where the majority carriers are depleted from the surface.

DEPLETION LAYER. The region of a semiconductor device where essentially all charge carriers are swept out by an electric field.

DIELECTRIC ISOLATION. The use of silicon dioxide barriers to provide isolation between devices of a circuit.

DIFFERENTIAL INPUT ISOLATION. On a switching card, the isolation from signal high to low. Specified as resistance and capacitance.

DIFFERENTIAL NON-LINEARITY. The maximum deviation of an actual quantized step width from the ideal quantized step width. *See* QUANTIZATION.

DIFFUSION. The introduction and subsequent redistribution of dopants in semiconductors using thermal techniques.

DIGITAL MULTIMETER (DMM). An electronic instrument that measures voltage, current, resistance, or other electrical parameters by converting the analog signal to digital information and display. The typical five-function DMM measures DC volts, DC amps, AC volts, AC amps, and resistance.

DIRECT DIGITAL SYNTHESIS. A technique for signal generation where the signal is directly synthesized using only digital techniques. This technique generates very precise waveforms, even at low frequencies. Waveforms with correct phase and frequency are obtained immediately after a shift to a new frequency.

DONOR. An impurity that makes a semiconductor N-type by donating electrons to the conduction band.

DOPANT. A selected impurity that is introduced into a semiconductor to control its conduction properties and form a junction.

DOPING PROFILE. A profile of doping concentration in atoms per unit area versus depth into the semiconductor.

DRIFT. A gradual change of a reading with no change in the input signal or operating conditions.

DRY CIRCUIT SWITCHING. Switching below specified levels of voltage (e.g., 20mV) and current to minimize any physical and electrical changes in the contact junction. *See also* COLD SWITCHING.

DRY REED RELAY. A glass-enclosed, hermetically sealed, magnetically actuated contact. No mercury or other wetting material is used.

Glossary

Dual In-line Package (DIP). A plastic or ceramic package with two rows of vertical leads.

Duty Ratio. The ratio of pulse width to repetition period. Also known as *Duty Cycle.*

Electrometer. A highly refined DC multimeter. In comparison with a digital multimeter, an electrometer is characterized by higher input resistance and greater sensitivity. It can also have functions not generally available on DMMs (e.g., measuring electrical charge, sourcing voltage).

Epitaxial Layer. A deposited layer of material having the same crystallographic characteristics as the substrate material.

Equilibrium. The time at which a capacitor has completely responded to a given applied voltage.

Fall Time. The time required for a signal to change from a large percentage (usually 90%) to a small percentage (usually 10%) of its peak-to-peak amplitude. *See also* Rise Time.

Feedback Charge. Feedback charge quasistatic CV is the technique developed by Keithley to measure CV at very low effective frequencies. It is based on the static technique and Q-V technique.

Floating. The condition where a common mode voltage exists between an earth ground and the instrument or circuit of interest. (Low of circuit is not at earth potential.)

Four-terminal Resistance Measurement. A measurement where two leads are used to supply current to the unknown and two different leads are used to sense the voltage drop across the resistance.

Gate Oxide. The thin, high quality silicon dioxide layer in the MOSFET gate region.

Guarding. A technique that reduces leakage errors and decreases response time. Consists of a guard conductor driven by a low-impedance source surrounding the lead of a high-impedance signal. The guard voltage is kept at or near the potential of the signal.

Hall Effect. The measurement of the transverse voltage across a conductor when placed in a magnetic field. By this measurement, it is possible to determine the type, concentration, and mobility of carriers in silicon.

Hot Junction. The junction of two dissimilar metals in a thermocouple circuit that is used to measure an unknown temperature. Also known as *measurement junction.*

Input Bias Current. The current that must be supplied to the high input measuring terminal (with zero input signal and offset voltage) to reduce the output indication to zero.

Input Impedance. The shunt resistance and capacitance (or inductance) as measured at the input terminals, not including effects of input bias or offset currents.

Input Isolation. On a switching card, the isolation from signal high to low (or guard) for a two-pole circuit. Specified as resistance and capacitance.

Input Offset Current. The difference between the two currents that must be supplied to the input measuring terminals of a differential instrument to reduce the output indication to zero (with zero input voltage and zero offset voltage).

Input Offset Voltage. The voltage that must be applied directly between the input measuring terminals, with bias current supplied by a resistance path, to reduce the output indication to zero.

Insertion Loss. The attenuation of signals due to routing them through a switching card. Specified as a decibel value over a frequency range.

Insulation Resistance. The ohmic resistance of insulation. It degrades quickly as humidity increases.

Integrating Conversion. An analog to digital conversion process where the output results in a digital representation of the integral of the input signal over a specified time interval.

Interface Traps. Defects in the semiconductor that allow for the trapping of charge between the valence and conduction band. The density of interface traps is referred to as D_{IT}.

Inversion. The region of operation in a MIS capacitor where the majority carriers are completely depleted from the surface and minority carriers are all that remain.

Isolated Outputs. Output signals where a common reference is not connected to either input terminal.

Jitter. The short-term variation of timed events. *See* Aperture Jitter, Timing Jitter, *and* Trigger Jitter.

Leakage Current. Error current that can degrade sensitive measurements. Even high resistance paths between low current conductors and nearby voltage sources can generate significant leakage currents.

Linearity. The maximum deviation from a straight line between instrument readings at zero and full range. It is expressed in ppm at a specific temperature.

Long-term Accuracy. The limit that errors will not exceed during a 90-day or longer time period. It is expressed as a percentage of reading (or sourced value) plus a number of counts over a specified temperature range.

Mainframe. A self-contained instrument in a cabinet, which provides a measurement or connection capability without requiring other instruments in the circuit. Some mainframes may be designated as a "master" or "slave". *See also* Switching Mainframe, Master, and Slave.

Majority Carrier. The mobile charge carriers (holes or electrons) that predominate in a semiconductor material.

Make-before-break. Connecting a new circuit before disconnecting the present circuit.

Master. A mainframe that has control of other mainframes (slaves) through an external connection. A slave unit adds capacity or functions to the master. The master/slave combination has one IEEE-488 bus address. *See also* Slave and Mainframe.

Glossary

Matrix Card. A type of card with a switching configuration that has columns and rows of relay crosspoints. (Also called a *coordinate switch.*) With a matrix card, since any one point can be connected to any other, you can simultaneously have one input with multiple outputs, multiple inputs with one output, or multiple inputs with multiple outputs.

Maximum Allowable Input. The maximum DC plus peak AC value (voltage or current) that can be applied between the high and low input measuring terminals without damaging the instrument.

Mercury Wetted Relay. A reed relay in which the contacts are wetted by a film of mercury. Usually has a required operating position to avoid liquid mercury shorting the contacts; other types are position insensitive.

Minority Carrier. The non-predominant mobile charge carriers in a semiconductor material.

MIS. Metal insulator semiconductor.

Mobility. A measure of the speed at which carriers move through doped semiconductor material per unit of electric field.

MOS. Metal oxide (a type of insulator) semiconductor.

MOSFET. Metal oxide semiconductor field effect transistor. A unipolar device characterized by extremely high input resistance.

Multiplex. Connecting one instrument to multiple devices under test or multiple instruments to one device under test. *See also* Scan.

Nanovoltmeter. A sensitive DC voltmeter (typically one decade more sensitive than a digital multimeter) with a low thermal input connection.

Normal Mode Rejection Ratio (NMRR). The ability of an instrument to reject interference (usually of line frequency) across its input terminals. Usually expressed in decibels at a frequency.

Normal Mode Voltage. A voltage applied between the input high and input low terminals of an instrument.

Offset Current. A current that comes from a switching card even though no user signals are applied. It comes mostly from the finite coil to contact impedance. It is also generated by triboelectric, piezoelectric, and electrochemical effects present on the card.

Overload Protection. A circuit that protects the instrument against excessive current at the input terminals.

Oxidation. The growth of a layer of silicon dioxide on a silicon surface.

Path. One of many signal paths on a matrix switching card. A path is established by the actuation of a relay at a row and column crosspoint. *See also* Channel.

Path Isolation. On a matrix switching card, the isolation from signal high and low of one path to signal high and low of any other path. Specified as *resistance* and *capacitance. See also* Channel Isolation.

Path Resistance. On a matrix switching card, the resistance per conductor of a closed path, including the tape resistance and connector terminal resistance. *See also* Contact Resistance.

Peak Responding. A measurement where the displayed value is equal to the peak value of the input signal.

Picoammeter. A measuring instrument that is similar in function to the ammeter of an electrometer. General differences include: as low or lower voltage burden, faster readings, and less sensitivity.

Pole. A combination of mating relay contacts: normally open, normally closed, or both.

Quantization. A process where the continuous range of values of an input signal is divided into non-overlapping sub-ranges and, to each sub-range, a discrete value of the output is uniquely assigned.

Quasistatic Capacitance. The capacitance of a semiconductor device measured at such a low frequency that the system (DUT) is in thermal equilibrium (both interface traps and minority carriers immediately follow AC gate voltage and changes in gate bias).

Range. A continuous band of signal values that can be measured or sourced. In bipolar instruments, range includes positive and negative values.

Rated Accuracy. The limit that errors will not exceed when the instrument is used under specified operating conditions. It is expressed as a percentage (of input or output) plus a number of counts. *See also* Absolute Accuracy.

Ratio Measurement. The measurement of a signal input with relation to an external reference input.

Reading. The displayed number that is proportional to the measured magnitude of the input signal.

Reading Rate. The rate at which the displayed number is updated.

Relay Must-operate Value. A specified functioning value at which all relays meeting the specifications must operate. Also known as *relay pick-up* or *pull-in value.*

Relay Must-release Value. A specified functioning value at which all relays meeting the specifications must release. Also known as *relay drop-out value.*

Release Time. The time between the removal of the relay coil voltage and the stabilized opening of the relay contacts.

Repeatability. The ability of an instrument to measure the same input to the same value over a short period of time and over a narrow temperature range.

Resistance Insertion. A current measuring technique where a known resistor is connected in series with the circuit to be measured. The voltage drop across the resistor is proportional to the unknown current.

Resolution. The smallest value of input (or output) signal, other than zero, that can be measured (or sourced) and displayed. Also called *sensitivity* or *minimum resolvable quantity.*

Glossary

Response Time. For a measuring instrument, the time between application of a step input signal and the indication of its magnitude within a rated accuracy. For a sourcing instrument, the time between a programmed change and the availability of the value at its output terminals. Also known as Settling Time.

Rise Time. The time required for a signal to change from a small percentage (usually 10%) to a large percentage (usually 90%) of its peak-to-peak amplitude. *See also* Fall Time.

RMS Responding. A measurement where the displayed value is equal to the root-mean-square (*rms*) of the input signal, for all input waveforms having components within the specified frequency range and crest factor limit.

Row. As viewed on the schematic of a matrix relay card, the horizontal signal lines or a horizontal group of relays.

Sampling Rate. The frequency that the input signal is sampled.

Scan. Sequential connecting (usually break-before-make) of one instrument to multiple devices under test or multiple instruments to one device under test. *See also* Multiplex.

Sensitivity. *See* Resolution.

Settling Time. For a measuring instrument, the time between application of a step input signal and the indication of its magnitude within a rated accuracy. For a sourcing instrument, the time between a programmed change and the availability of the value at its output terminals. For a switching card, the time required for establishing relay connections and stabilizing user circuits. Also known as Response Time.

Shielding. A metal enclosure for the circuit being measured or a metal sleeve surrounding wire conductors (coax or triax cable) to lessen interference, interaction, or current leakage. The shield is usually grounded.

Shunt Capacitance Loading. The effect on a capacitance meter of capacitance, such as from cables or fixtures, between the meter input or output terminals and guard (sometimes referred to as common). Shunt capacitance reduces the measured device current. Therefore, the measured device capacitance is smaller.

Short-term Accuracy. The limit that errors will not exceed during a 24-hour period of continuous operation. Unless specified, no zeroing or adjustments of any kind are permitted. It is expressed as a percentage of reading (or sourced value) plus a number of counts over a specified temperature range.

Signal/Noise Ratio. The ratio of the maximum signal that can be measured to the level detected with no signal present (noise level). It is expressed in decibels.

Single-ended. The condition where the low terminal of a two-terminal instrument is connected to a specific reference point, such as power line common, earth ground, or circuit common.

Slave. A mainframe that is externally connected to a controlling mainframe (master). A slave unit adds capacity or functions to the master. *See also* Master and Mainframe.

Slew Rate. The maximum charge rate of the signal sampling capacitor in the sample and hold circuit of an A/D converter. It is expressed in volts/microsecond.

Source Impedance. The combination of resistance and reactance that a source presents to the input terminals of a measuring instrument.

Source/Measure Unit (SMU). An electronic instrument that sources and measures DC voltage and current. Generally, SMUs have two modes of operation: source voltage and measure current, or source current and measure voltage. Programmable features can include: constant or sweep source, measurement delays, and compliance levels. Also known as a source/monitor unit or a stimulus/measurement unit.

Spectral Purity. A description of the distortion components of an oscillator's output signal at a specified amplitude and load. Includes total harmonic distortion, harmonics, and spurious components.

Spurious Components. Undesired signals in the output of a signal generator that have a defined amplitude and frequency. They are not harmonically related to the fundamental frequency. Specified as decibels below the carrier frequency.

Standoff Potential. The breakdown voltage across relay contacts.

Substrate. The underlying material upon which a device circuit or epitaxial layer is fabricated.

Switch. Connecting one input to one output. Also known as *actuate.*

Switch Card. A type of card with independent and isolated relays for switching inputs and outputs on each channel.

Switched Current. The maximum current level that can be reliably handled while opening and closing contacts. *See also* Carry Current.

Switching Mainframe. A switching instrument that operates according to user commands to connect signals among sourcing and measuring instruments and devices under test. A mainframe is also referred to as a *scanner, multiplexer, matrix,* or *programmable switch.*

Temperature Coefficient. A change in reading (or sourced value) with a change in temperature. It is expressed as a percentage of reading (or sourced value), plus a number of counts per degree change in temperature.

Temperature Coefficient of Resistance. The amount of resistance change of a material per degree of temperature change.

Thermoelectric Voltage. Voltages resulting from temperature differences within a measuring circuit or when conductors of dissimilar materials are joined together. Also known as *thermal EMF* or *thermal offset. See* Contact Potential.

THRESHOLD VOLTAGE (V_T). The gate voltage needed to turn on a MOS enhancement-mode device.

TIMEBASE ACCURACY. A measure of how closely the internal timebase of an instrument tracks a known time standard.

TIMING JITTER. The short-term variation of the time period between sample points.

TOTAL HARMONIC DISTORTION. The percentage of harmonic distortion present in an output signal over a specified frequency range.

TRANSFER ACCURACY. A comparison of two nearly equal measurements over a limited temperature and time. It is expressed in ppm.

TRIGGER. An external stimulus that initiates one or more instrument functions. Trigger stimuli include: an input signal, the front panel, an external trigger pulse, and IEEE-488 bus X, Talk, and GET triggers.

TRIGGER JITTER. The short-term variation of the time period between a trigger event and the first sample point.

TRIGGER LATENCY. The fixed time offset between the trigger event and the first sample point.

TWO-TERMINAL RESISTANCE MEASUREMENT. A measurement where the same current flows through the unknown and the test leads.

VOLTAGE BURDEN. The voltage drop across the resistor for the resistance insertion technique of current measurement.

VOLTAGE STANDING WAVE RATIO (VSWR). For a switching card, the loss due to the mismatch introduced into the signal by the card contacts and conductors. Expressed as a ratio of the highest voltage to the lowest voltage found in the signal.

WAFER. A slice from an ingot (material prepared by solidification from a melt) on which semiconductor devices are made.

WAFER PROBING. An electrical test of devices on the wafer, using small probes to make contact with the metallized pads on the die.

WARM-UP TIME. The time required after power is applied to an instrument to achieve rated accuracy at referenced conditions.

ZERO OFFSET. The reading (desired or undesired) that occurs when the input terminals of a measuring instrument are shorted.

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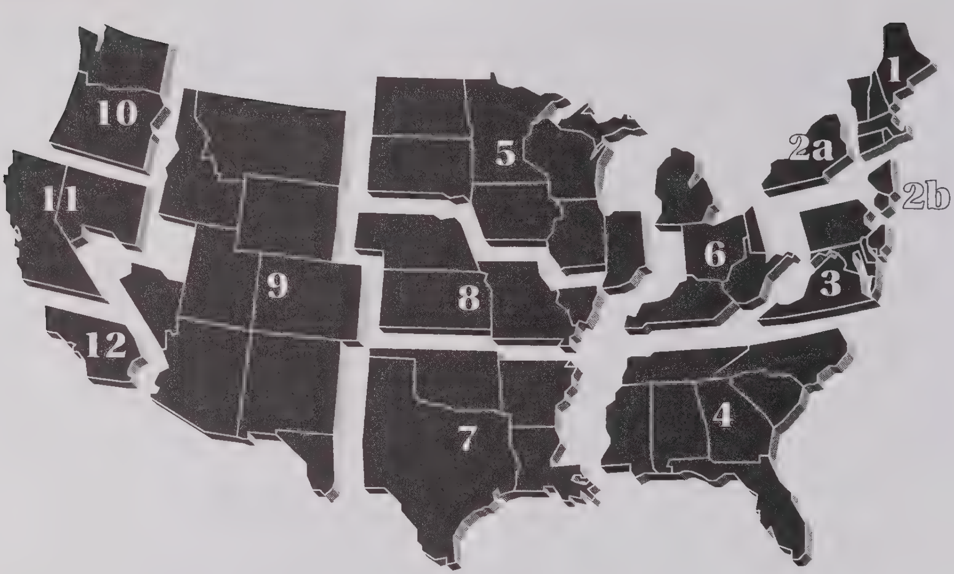

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(216) 248-0818

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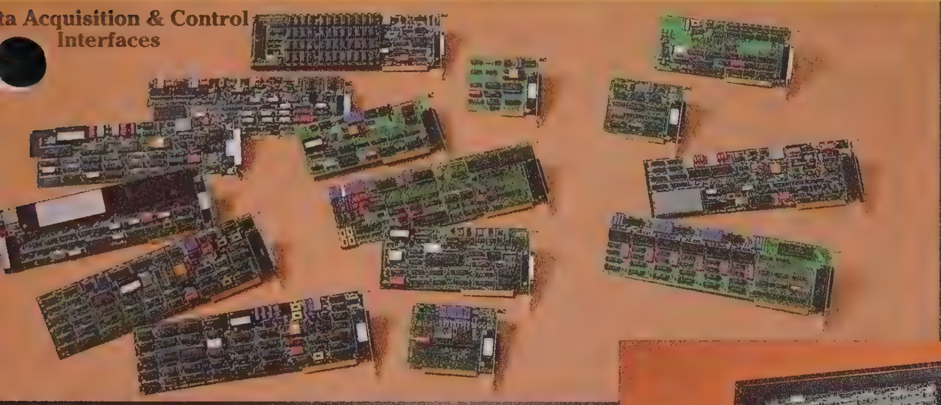
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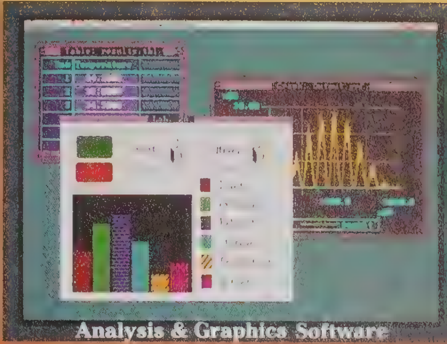
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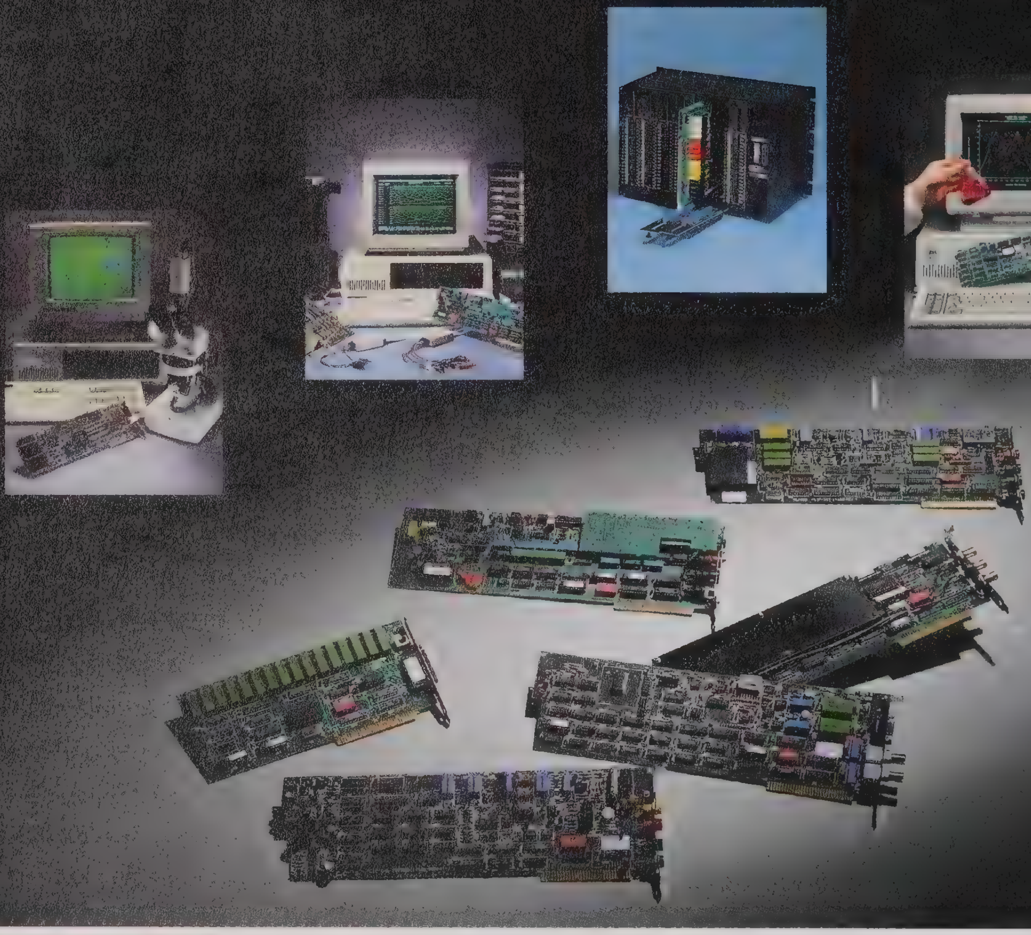

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☐ Application Notes ______________________

____

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☐ Low Level Measurements Handbook

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☐ My application(s): ______________________

____

☐ Demonstration of model(s): ______________________

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☐ 3–6 month: ______________________

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☐ 4 Electrometers/Picoammeters

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☐ 6 Resistance Meas. Instruments

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☐ Demonstration of model(s): ______________________

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Type of Facility: Check only one

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☐ 3 Design

☐ 4 Calibration Lab/ Instrument Pool

☐ 5 Production Test

☐ 6 Component Test

☐ 8 Quality Assurance/Control

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1987-1988 Catalog and Buyer's Guide

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Table of Contents

MEASUREMENTS: An Introduction 2

DIGITAL MULTIMETERS

Selector Guide 4
Technical Data 6
169 / 3½-Digit Portable / Bench DMM 8
179A, 177 / 4½-Digit Bench DMM 9
175 / Autoranging 4½-Digit Bench DMM 10
197 / Autoranging 5½-Digit Bench DMM 12
195A / System DMM 14
196 / System DMM 16
193A / High Speed System DMM 19
194A / High Speed Digitizer 21
Accessories Selector Guide 24

OTHER MEASUREMENT INSTRUMENTS

580 / Micro-ohmmeter 25
740 / System Thermometer 27
775A / Counter / Timer 29

ELECTROMETERS, PICOAMMETERS

Selector Guide 31
Technical Data 32
617 / Electrometer/Source 36
614 / Electrometer 38
619 / Electrometer 40
642 / Electrometer 42
602, 610C / Electrometers 44
427 / Amplifier 45
485, 480 / Picoammeters 46
18000-20, 26000 / Log Picoammeters 48
Accessories Selector Guide 49

CV MEASUREMENTS

590 / CV Analyzer 50
595 / Quasistatic CV Meter 55

NANOVOLTMETERS

Technical Data 58
181 / Nanovoltmeter 60
262 / Voltage Divider 61
155 / Microvoltmeter 62

SOURCES: An Introduction 63

SOURCES AND SUPPLIES

Selector Guide 64
220, 230 / Programmable Sources 65
224 / Programmable Current Source 67
228 / Programmable Current/Voltage Source 68
247 / High Voltage Supply 70
261 / Picoampere Source 71

CONNECTIONS: An Introduction 72

SCANNERS AND SWITCHING CARDS

705, 706 / Scanners 74
Selector Guide / Switching Cards 76
7052 / 5×4 Matrix Card 77
7053 / High Current Card 77
7054 / High Voltage Card 77
7056 / General Purpose Card 78
7057A / Thermocouple Card 78
7058 / Low Current Card 79
7059 / Low Voltage Card 79
7061 / Universal Adapter Card 80
7062, 7063 / RF Cards 80
7064 / 20-Channel Low Voltage Card 80
7066 / Relay Switch Card 81
7067 / 4-Wire Resistance Card 81
7158 / Low Current Card 82
7168 / Nanovolt Card 82
7402 / Thermocouple Card 78

HALL EFFECT MEASUREMENTS 83

IEEE-488 INTERFACE & SOFTWARE ...84

ACCESSORIES 85

DATA ACQUISITION & CONTROL: An Introduction 98

Series 500 / Data Acquisition Workstation 102
System 570 / Data Acquisition Workstation 104
Selector Guide / Data Acquisition Modules 106
Comparing Data Acquisition Software 129
Data Acquisition Accessories 138
Configuring a Data Acquisition System 139

SOFTWARE 140

DADiSP 140
Labtech Notebook 142
ASYST, ASYSTANT 144

SYSTEMS DIVISION 146

RADIATION MEASUREMENTS DIVISION 148

Index: Model Numbers 150
Substitution List 152
Ordering/Service Information 153
U.S. Representatives 154
International Representatives 155
European Representatives 156

Measuring: A Difficult Task Made Easier

The measurement aspect of a test system is usually considered the most important, and also the most difficult to implement. It is important to choose a measuring instrument which adds only an insignificant amount of error to the signal from the device under test (DUT). Thus, if noise, drift, and other sources of error which disturb the signal from the DUT are minimized, the system easily meets the stated objectives in terms of error, repeatability, accuracy, etc.

For the last 40 years, Keithley has been a leader in the electronic measurement industry, providing very sensitive instruments which can measure extremely small changes in current and voltage as well as extremely high resistances. In recent years, we have also become known for providing high-value DMMs and a variety of other test instruments.

We feel that it is not enough to provide just a sensitive, high-value instrument. It is also important to make it as easy as possible for you, the user, to make quality measurements confidently. To this end, our measuring instruments are designed such that they add only insignificant errors to the measured signal. They are designed to do this in a way which also minimizes the time and effort you have to spend solving measurement problems and getting valid data.

For example, our lowest-cost 20,000-count DMM, the Model 175, includes conveniences such as a built-in data memory, the ability to take relative readings, and an optional IEEE-488 computer interface. Such features are usually found only in DMMs costing twice as much. Our low-cost picoammeter, the Model 485, has these same convenience features along with 0.1pA sensitivity and only 200µV voltage drop at the input terminals. This low voltage burden (see page 46) makes it possible to measure current accurately even in voltage loops involving a source as low as 1V or less. And it is priced below most DMMs, which have much less current sensitivity and higher input voltage drop.

We also provide a phone-in applications service, staffed by highly trained engineers, to provide you with additional assistance in solving measurement problems and choosing the most appropriate measuring instruments for your needs. Application notes and booklets discussing various measurement examples are also available from Keithley.

TYPES OF MEASURING INSTRUMENTS

Presented here are guidelines for choosing the right type of measuring instrument. At the front of each of the DMM, electrometer/picoammeter, and nanovoltmeter sections of this catalog are descriptions of measurement considerations related to the type of instrument. Also included are Selector Guides which will help determine the best instrument for your needs.

VOLTS-AMPS-OHMS measurements are most often made using a **DMM (Digital Multimeter)**. A useful guideline is that if a DMM will do your job, it is usually the most cost-effective solution. These instruments are the ''workhorses'' of most laboratories and test areas. As you can see in the Selector Guide (page 4), a wide variety of accuracy, resolution, speed, and features is available. With the exception of the very low-cost Model 169 2000-count DMM, all Keithley DMMs have optional or built-in IEEE-488 computer interfaces. If the sensitivity (smallest detectable change in voltage, current, or resistance) required is better than a few hundred nV, pA, or µΩ, the more specialized instruments described below are needed.

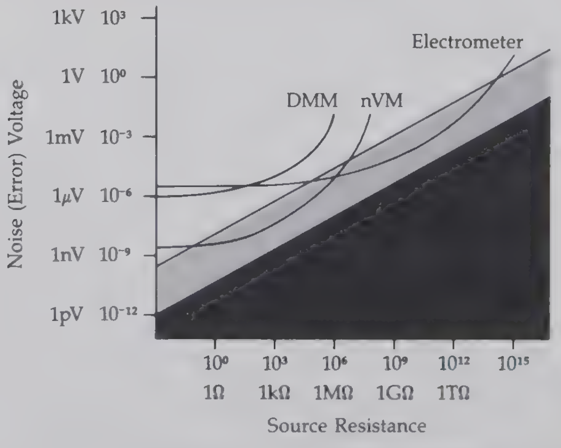
Nanovoltmeters are voltage-measuring instruments which are more sensitive than DMMs, as shown in **Figure 1**. For example, the Model 181 digital nanovoltmeter (page 60) is at least a decade more sensitive than DMMs. By averaging a string of readings, standard deviations between sets of averaged readings can be as low as a few nanovolts. Nanovoltmeters have special connectors for minimizing thermal EMFs in the connections.

With the Model 7168 nanovolt scanner card (page 82), it is now possible to automatically switch between signals at the nanovolt level. This new card is the most sensitive nanovolt switch available.

Electrometers are dc multimeters with very high input resistance (up to 10^{16} ohms) and very low input current (down to 10^{-17} amperes). As **Figure 1** shows, at high source resistances, an electrometer is far superior to either a DMM or a nanovoltmeter, due to its low input current. In addition to dc voltage and current capabilities, electrometers also measure charge and resistance. To measure resistance, they use an internal current source to generate low test currents. The Model 617 (page 36) also has a built-in voltage source for making direct resistance measurements up to 10^{16} ohms (by applying a voltage and measuring a current), as well as a built-in IEEE-488 computer interface.

Picoammeters are used in situations where only current is to be measured. While they are lower in cost than electrometers, they are not as sensitive, but they still have much better current sensitivity than a DMM. Both electrometers

FIGURE 1: Typical Digital Multimeter (DMM), Nanovoltmeter (nVM), and Electrometer Limits of Measurement at Various Source Resistances



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and picoammeters have much lower input voltage burden than DMMs. This makes them better suited for situations where the 200mV input voltage burden of a DMM would cause a significant measurement error (see the discussion of voltage burden on page 32).

A **Micro-ohmmeter** is needed to measure milliohm level resistances with precision. The Model 580 (page 25) provides a choice of waveforms, provisions for clamping the voltage to industry standard maximum levels, many DMM features, and a variety of test leads to minimize the effort required to make such sensitive measurements. Note that **Nano-ohm** resistances can be measured using a current source such as the Model 228 (page 68) and a nanovoltmeter such as the Model 181 (page 60).

For **Hall Effect** studies, a specialized card, the Model 7065 (page 83), has been added to the line. This provides all the necessary measurement and switching capability, cables, and an example program, making it as easy as possible to make Hall Effect measurements.

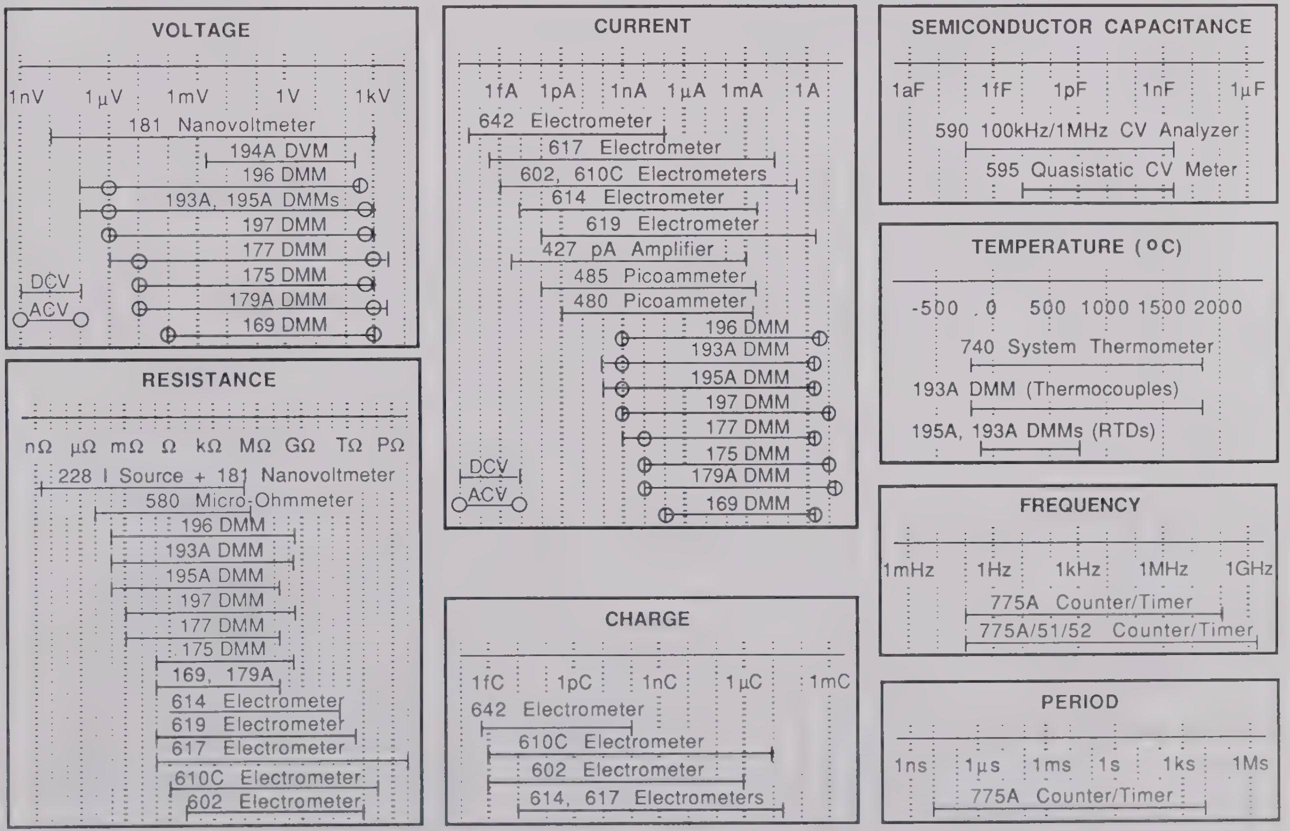
CV (Capacitance vs. Voltage) Measurements are often made on semiconductor wafers to characterize gate oxide and surface states. Two impressive new instruments in this catalog make CV measurements: the Model 590 CV Analyzer (page 50), which has 100kHz and/or 1MHz test frequency, and the Model 595 Quasistatic CV Meter (page 55). The Model 595 uses the ''feedback charge'' technique, pioneered by Keithley, which provides more information and requires less set-up time than older techniques.

TEMPERATURE measurements can be made directly using the Model 740 (page 27). This is a system thermometer providing direct temperature readout to the display or to a computer when used with any standard thermocouple. The 7402 Scanner Card (page 78) may also be used to cost-effectively expand from 1 to as many as 81 channels. Alternately, a thermocouple scanner card such as the Model 7057A (page 78) may be used with a system DMM such as the Model 196 (page 16) to provide a voltage reading corresponding to temperature. Another way of measuring temperature is with a Model 193A (page 19), which provides a precision temperature readout using a standard 100Ω platinum thermometer.

FREQUENCY and **PERIOD** may be measured with the Model 775A Programmable Counter/Timer (page 29). The enhanced version in this catalog measures frequencies to 1.3GHz, and can also accumulate a count of pulses or events.

For more information, application assistance, or a demonstration of Keithley's problem-solving measurements, contact your local sales engineer or Keithley Instruments office.

FIGURE 2: Keithley's Range of Measurements



Selector Guide/Digital Multimeters

MODEL	169	179A	175	177
Page	8	9	10	9
Maximum Display	1 999	19 999	19 999	19 999
Digits	3½	4½	4½	4½
Display	LCD	LED	LCD	LED

DC VOLTS

Sensitivity	100 μV	10 μV	10 μV	1 μV
Maximum Reading	1000 V	1200 V	1000 V	1200 V
Basic Accuracy	0.25%	0.04%	0.03%	0.03%

AC VOLTS[1]

Method	Average	TRMS	TRMS	TRMS
Sensitivity	100 μV	10 μV	10 μV	10 μV
Maximum Reading	1000 V	1000 V	750 V	1000 V
Basic Accuracy	0.75%	0.5%	0.5%	0.5%

OHMS

Special Features	Diode test on 20kΩ range	HI-LO switch selectable	Diode test	Front panel lead compensation
Sensitivity	100 mΩ	100 mΩ	10 mΩ	1 mΩ
Maximum Reading	20 MΩ	20 MΩ	200 MΩ	20 MΩ
Basic Accuracy	0.2%	0.04%	0.05%	0.04%

DC AMPS[1]

Sensitivity	100 nA	10 nA	10 nA	1 nA
Maximum Reading	2 A	20 A	10 A	2 A
Basic Accuracy	0.75%	0.2%	0.15%	0.2%

AC AMPS[1]

Method	Average	TRMS	TRMS	TRMS
Sensitivity	100 nA	10 nA	10 nA	10 nA
Maximum Reading	2 A	20 A	10 A	2 A
Basic Accuracy	1.5%	1.0%	0.8%	0.8%

IEEE-488 INTERFACE

Configuration	—	Option	Option	Option
Programmable Parameters	—	Trigger, Talk Only	Range (V, Ω), dB, calibration, relative reference	Trigger, Talk Only

Digital Calibration	—	—	Front panel or bus (with IEEE-488 option)	—
Ranging	Manual	Manual	Auto/Manual	Manual
Inputs	Front	Front	Front	Front
Battery Operation	Standard. AC optional	Optional 6-hour	Optional 6-hour	Optional 6-hour
Special Features	Function & range annunciators. 15mm digits. 1-year battery. Float up to 1.4kV.	1kV protection on Ω. Float up to 1.4kV. 20A ac, dc current. BCD output option.	100-point data logger. dB mode. Relative reference.	1μV, 1nA, 1mΩ sensitivity. Analog output. BCD output option.

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[1] Optional on Models 193A and 195A.

197	195A	196	193A	194A
12	14	16	19	21
219 999	199 999	3 029 999	2 199 999	32 000
5½	3½-5½	3½-6½	3½-6½	4½
LCD	LED	LED	LED	LED

1 μV	100 nV	100 nV	100 nV	10 μV
1000 V	1000 V	300 V	1000 V	200 V
0.011%	0.025%	0.003%	0.003%	0.03%

TRMS	TRMS	TRMS	TRMS
1 μV	1 μV	1 μV	1 μV
750 V	700 V	300 V	700 V
0.35%	0.3%	0.15%	0.25%

Auto 2/4 terminal Diode test	Auto 2/4 terminal	Auto 2/4 terminal	Auto 2/4 terminal
1 mΩ	100 μΩ	100 μΩ	100 μΩ
220 MΩ	20 MΩ	300 MΩ	220 MΩ
0.018%	0.025%	0.005%	0.005%

1 nA	100 pA	1 nA	1 nA
10 A	2 A	3 A	2 A
0.1%	0.09%	0.05%	0.09%

TRMS	TRMS	TRMS	TRMS
1 nA	1 nA	1 nA	1 nA
10 A	2 A	3 A	2 A
0.8%	0.6%	0.6%	0.6%

- Waveform acquisition
- Waveform analysis
- Simple system integration.

Product Features:

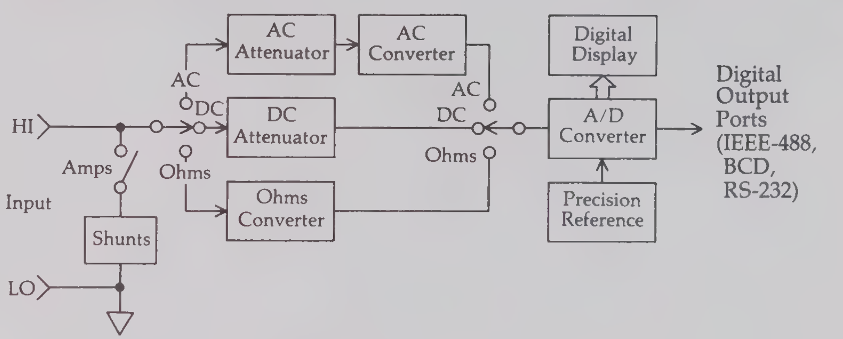
- High speed programmable sampling:
  16 bit resolution up to 100kHz
  8 bit resolution 100kHz to 1MHz
- 2 independent and isolated measurement channels (2nd channel optional)
- 64K bytes data memory per channel (90K bytes/second transfer rate over IEEE-488 bus)
- External sample strobe rate to 1M/second

Option	Included	Included	Included	Included
Range (V, Ω), dB, memory, calibration, relative reference	All functions and features	All functions and features	All functions and features	All functions and features

Front panel or bus (with IEEE-488 option)	Front panel or bus	Front panel or bus	Front panel or bus	Front panel or bus
Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual
Front	Front/Rear	Front/Rear	Front/Rear	Rear
Optional 5-hour	—	—	—	
Analog + IEEE-488 output option. 100-point data logger. dB mode. Relative reference.	100-point data logger. RTD temperature. Front panel messages. Pushbutton zero.	1000 readings/second. 500-point data logger over bus. Non-volatile TRANSLATOR. Offset compensated ohms. Front panel programs.	500-point data logger. RTD and TC temperature. 1000 rdg/second. Non-volatile TRANSLATOR. Low frequency TRMS AC. dB.	Real time data port. Analog output. Independent time bases. Synchronize up to 8 channels. Five trigger sources.

Digital multimeters convert analog signals to digital information. The typical five-function DMM measures dc volts, dc amps, ohms, ac volts, and ac amps. While specifics may vary, virtually every DMM is developed around the same block diagram (**Figure 1**).

FIGURE 1: DMM Block Diagram



Analog-to-Digital Conversion

The A/D converts the analog input signal to a digital output, and is principally responsible for the key instrument characteristics of reading speed, linearity, resolution, normal mode rejection, and precision. The digital output can be sent to one of several ports including front panel display, or to computer interfaces such as GPIB or RS 232.

Many bench and handheld instruments use a single-chip dual slope conversion circuit for simplicity and convenience. Programmable instruments generally use the capability of the microprocessor and variations on charge balance or successive approximation techniques to achieve higher resolution and speed.

Resolution

Resolution is defined as the smallest detectable change on any range referenced to full scale. For example, if an instrument will display a maximum value of 1999 on any range, and the smallest detectable change in the input signal is ±1 LSD, then the resolution is 1/1999 or 0.05%.

Resolution is commonly expressed as a whole number plus a fraction, e.g., 4½ digits. The whole number represents the number of digits which can display 0-9. The fraction indicates that the most significant digit has one or more non-zero states; that is, it can display 0, 1, or 2.

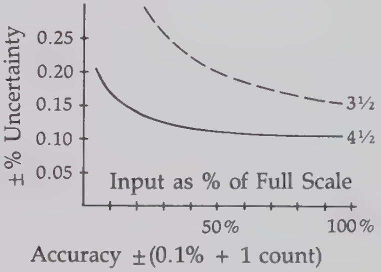
Sensitivity

Sensitivity is like resolution in that it deals with the smallest change of the input signal the instrument can detect. However, since sensitivity is not referenced to full scale, it is expressed in absolute terms, and applies to the lowest range on any function. The sensitivity of a 5½-digit DMM is $1\mu V$ if the lowest measurement range is 200mV.

Accuracy

Accuracy is specified as ±(% reading + offset counts), and is generally stated under several different conditions including ±1°C, ±5°C operating temperature, and 24-hour, 90-day, and 1-year calibration intervals. The expected accuracy can be improved by controlling temperature variations in the environment and by electing more frequent calibration intervals. **Figure 2** illustrates the effect on accuracy at various levels of input signal within the measurement range. Accuracy for both meters is specified at ±(0.1% + 1 count). The best accuracy is obviously obtained near full scale.

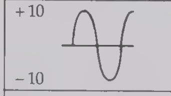
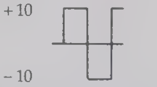
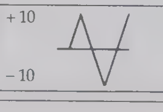
FIGURE 2: Expected Reading Uncertainty 3½- vs. 4½-Digit DMMs



True RMS and Average Responding Meters. DMMs convert ac signals to dc voltages to be measured by the A/D converter. The ac converter may be either a true RMS or an averaging type. Both will respond with the same output value for a sine wave input. However, signals other than sine waves produce an error in the displayed value when measured with an average responding meter.

Figure 3 illustrates resultant error for three common types of waveforms. For irregular waveforms, it is better to use a True RMS meter.

FIGURE 3: True RMS vs. Averaging DMMs

	Waveform	RMS Value of Waveform	True RMS Reading	Average DMM Reading	Error for Average Meter
Sine		14.14V	14.14V	14.14V	0%
Square		10.00V	10.00V	11.11V	11.1%
Triangular		5.77V	5.77V	5.55V	3.8%

Loading/Input Impedance

Loading is the disturbance of the circuit being measured caused by the finite input impedance of the DMM. Input impedance is the equivalent resistance and capacitance looking into the DMM at the input terminals.

Loading Error. The difference between the voltage measured by the meter (V_M) and the voltage of an ideal source (V_S) is the loading error (**Figure 4**).

Voltage Burden Error is the difference between the expected current through load R_L and the measured current I_M caused by the finite voltage drop of he measuring instrument (**Figure 5**).

Ohmmeter Full Scale Voltage is the voltage that will be present across the measurement circuit when the resistance of the circuit is near full scale. The voltage is developed by the test current flowing through the unknown and the interconnect wiring. When doing in-circuit resistance checks, the full scale voltage should be well below the turn-on voltage of any semiconductor junctions. Some meters have special HI and LO functions for reducing the ohmmeter full scale voltage. In addition, many meters have special diode testing ranges.

2-Wire vs. 4-Wire Ohms (Figure 6). Two-terminal DMMs source test current through the measuring test leads, terminating at the HI-LO inputs of the DMM. This two-wire ohms system works fine for 3½-digit and most 4½-digit DMMs. However, the I-R drop in the test leads (R_l) can cause inaccuracies that become apparent on 5½-digit models.

Four-wire ohms or Kelvin measurements bypass the voltage drop across R_l by bringing two high impedance voltage sense leads out to the unknown R_X. Since there is very little current in the sense circuit, there is effectively no IR drop in the leads, and the voltage seen by the sense terminals is the same as the voltage developed across R_X.

FIGURE 6: 2-Wire vs. 4-Wire Ohms

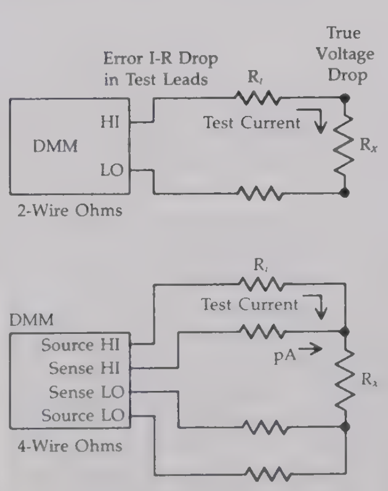
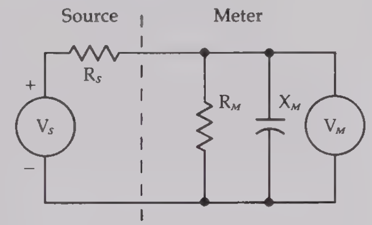


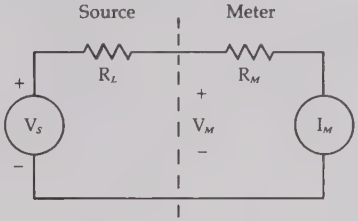
FIGURE 4: Loading Error



Loading Error $= -\frac{R_S}{R_S+Z_M}$ and $Z_M = \frac{R_M X_M}{R_M+X_M}$

Function	Increase	Effect on Loading Error
ACV or DCV	R_S	Increase
ACV or DCV	R_M	Decrease
ACV	C_M	Increase
ACV	Frequency	Increase

FIGURE 5: Voltage Burden Error



1. $I_S = \frac{V_S}{R_L}$ for $V_M = 0$ 2. $I_M = \frac{V_S - V_M}{R_L}$

Voltage Burden Error $= \frac{I_M - I_S}{I_S} = -\frac{V_M}{V_S}$

$V_M \propto \frac{I_M}{I_{FS}} V_B$ where V_B is the maximum burden voltage and I_{FS} is the full scale current

Speed and Settling Time. Every meter has a settling time associated with its input circuit. The reading rates or measurement speeds of instruments are independent of the settling times. For high resolution meters, it may be necessary to allow time for input settling in order to achieve full rated accuracy.

Normal and Common Mode Rejection

Normal mode interference is that which is mixed with the incoming signal. Most normal mode interference is at line frequency and harmonics. NMRR (Normal Mode Rejection Ratio) is specified in dB at line frequencies of 50Hz and 60Hz. Normal mode interference is detected as a peak noise or deviation in a dc signal.

$$\text{NMRR} = 20 \log \frac{\text{(peak measurement deviation)}}{\text{(peak normal mode interference)}}$$

CMRR (Common Mode Rejection Ratio) is the ability of a meter to reject signals common to both input HI and LO. This term is generally measured with a 1kΩ resistor imbalance in one of the leads. Larger imbalance will cause CMRR to be worse.

CMRR is specified at either dc, 50Hz or 60Hz, and like NMRR is expressed in dB. CMRR applies to both dc and ac measurements and appears as an offset error to the desired signal.

Digital Calibration. Microprocessor design techniques and non-volatile memories have brought about the ability to calibrate an instrument through computer control. This digital calibration improves reliability by eliminating mechanical trim components, ensures repeatability in procedures by allowing fully automated calibration, and makes it easy under computer control to build history files on individual instruments to determine long term trends.

Overload Protection is a measure of electrical ruggedness, and should be sufficient to protect the meter from line voltages commonly encountered. Typically, the ranges most susceptible to high voltage are the lowest voltage range (200mV) and the ohms ranges.

Similar to overload protection is the maximum common mode voltage at which the meter can be used. This is the maximum voltage from earth ground that the input LO or COMMON terminal can withstand safely. The input LO terminal should always be at the lowest impedance point to minimize ground loops, and whenever possible should be connected to circuit COMMON for safety.

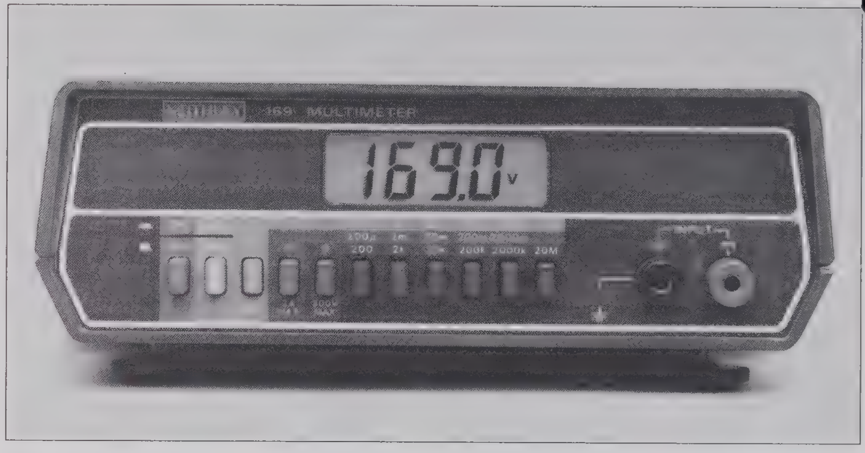
Power

Many Keithley DMMs have provisions for field installation of a rechargeable battery pack. This assures isolation from the power line and allows some degree of portability. The Ni-Cd batteries in these packs will power a typical bench instrument for five to six hours.

169/Digital Multimeter

3½ Digits, Battery Powered

- **Display annunciators indicate range and function**
- **2000 hour battery life**
- **Line power option**



The Keithley 169 provides full capability for many general purpose applications. It has five functions: dc volts, dc amps, ac volts, ac amps, and ohms. Sensitive down to 100μV, 100nA, and 100mΩ, the 169 spans the most used ranges up to 1000V, 2A, and 20MΩ. The full bench-sized case, molded from impact-resistant flame-retardant plastic, is the same case used on more sophisticated Keithley DMMs. Full input protection prevents damage: voltage ranges are protected to 1400V peak, ohms is protected to 300V rms, and current ranges are protected by an externally accessible 2A (250V) fuse.

The 169 has both range and function annunciators. Pushbutton switches are color-coded to the front panel. Two input jacks and auto polarity mean no lead changing.

By using alkaline batteries, 2000 hours (1 year) of operation can be expected. Thus, battery life can be the same as the calibration cycle. Only one calibration adjustment is required. MTBF is 20,000 hours, so most units will never need repair. If they do, all components are on one easily accessible pc board.

A line power option, Model 1766, can be installed in place of the batteries. This option, which includes a fully isolated power supply and 3-wire grounded line cord, operates over the entire voltage range of 105-250V ac, 50-60Hz, without switching.

DC VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year) ±(%rdg + counts) 18°-28°C
200 mV	100 μV	0.25 + 1
2 V	1 mV	0.25 + 1
20 V	10 mV	0.25 + 1
200 V	100 mV	0.25 + 1
1000 V	1 V	0.25 + 1

MAXIMUM ALLOWABLE INPUT: 1000V dc, 1400V peak ac.

INPUT RESISTANCE: 10MΩ.

NORMAL MODE REJECTION RATIO: >50dB at 50Hz, 60Hz.

COMMON MODE REJECTION RATIO: >100dB at dc, 50Hz and 60Hz (1kΩ unbalance, 500V).

AC VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year) ±(%rdg + counts) 18°-28°C 45Hz - 1kHz	1kHz - 5kHz
200 mV	100 μV	0.75 + 5	5 + 7
2 V	1 mV	0.75 + 5	5 + 7
20 V	10 mV	0.75 + 5	5 + 7
200 V	100 mV	0.75 + 5	5 + 7
1000 V	1 V	0.75 + 5	5 + 7

MAXIMUM ALLOWABLE INPUT: 1000V rms, 1400V peak, 10^6V•Hz, continuous except 200mV range: 350V continuous, 15s maximum above 350V.

RESPONSE: Average responding, calibrated in rms of a sine wave.

INPUT IMPEDANCE: 10MΩ shunted by <100pF.

OHMS

RANGE	RESOLUTION	ACCURACY (1 Year) ±(%rdg + counts) 18°-28°C	FULL SCALE VOLTAGE
200 Ω	100 mΩ	0.3 + 3	<0.5V
2 kΩ	1 Ω	0.2 + 1	>0.5V
20 kΩ	10 Ω	0.2 + 1	>0.7V
200 kΩ	100 Ω	0.2 + 1	>0.7V
2000 kΩ	1 kΩ	0.2 + 1	>0.7V
20 MΩ	10 kΩ	2.0 + 1	>0.7V

MAXIMUM OPEN CIRCUIT VOLTAGE: 1.5V except 200Ω range: 3.5V.

MAXIMUM ALLOWABLE INPUT: 300V dc or rms.

DC AMPS

RANGE	RESOLUTION	ACCURACY (1 Year) ±(%rdg + counts) 18°-28°C	MAXIMUM VOLTAGE BURDEN
200 μA	100 nA	0.75 + 1	0.25V
2 mA	1 μA	0.75 + 1	0.25V
20 mA	10 μA	0.75 + 1	0.25V
200 mA	100 μA	0.75 + 1	0.3 V
2000 mA	1 mA	0.75 + 1	0.7 V

OVERLOAD PROTECTION 2A fuse (250V), externally accessible.

AC AMPS

RANGE	RESOLUTION	ACCURACY (1 Year) ±(%rdg + counts) 18°-28°C	MAXIMUM VOLTAGE BURDEN
200 μA	100 nA	1.5 + 1	0.25V
2 mA	1 μA	1.5 + 1	0.25V
20 mA	10 μA	1.5 + 1	0.25V
200 mA	100 μA	1.5 + 1	0.3 V
2000 mA	1 mA	1.5 + 1	0.7 V

OVERLOAD PROTECTION 2A fuse (250V), externally accessible.

GENERAL

DISPLAY: 3½-digit LCD, 0.6 in. numeral height, with polarity, range, and function annunciators.

OVERRANGE INDICATION: 3 least significant digits blanked.

MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

OPERATING ENVIRONMENT: 0° to 50°C; <80% RH up to 35°C, <70% RH from 35° to 60°C.

STORAGE ENVIRONMENT: −35° to 60°C.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C.

POWER: Six 1.5V C cells. Battery life 1000 hours typical with C-Zn cells, 2000 hours with alkaline cells.

BATTERY INDICATOR: Display indicates "BAT" when less than 5% of battery life remains.

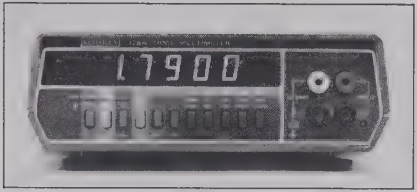
DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.4kg (3 lbs.).

ACCESSORIES SUPPLIED: Model 1691 Test Lead Set, operator's manual.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

Digital Multimeters/179A, 177

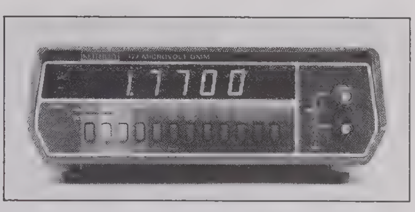
179A: 20A Range **177:** Analog Output



- **4½-digit LED displays**
- **TRMS AC**
- **IEEE-488 output option**

179A: HI-LO ohms, 20A range

177: 1μV/1mΩ/1nA, analog output



DC VOLTS

RANGE	RESOLUTION	179A ACCURACY[1]	177 ACCURACY[1]
20 mV	1 μV	—	0.04 + 2
200 mV	10 μV	0.04 + 3	0.04 + 1
2 V	100 μV	0.04 + 1	0.03 + 1
20 V	1 mV	0.04 + 1	0.03 + 1
200 V	10 mV	0.04 + 1	0.03 + 1
1200 V	100 mV	0.04 + 1	0.035 + 1

[1] Accuracy is specified for 1 year, 18°-28°C, ±(%rdg + counts).

TEMPERATURE COEFFICIENT (0°-18°C & 28°-55°C), ±(%rdg +counts)/°C: **179A:** ±(0.006% + 0.2)/°C except ±(0.006 + 0.4)/°C on 200mV range. **177:** ±(0.005% + 0.1)/°C except ±(0.005% + 0.6)/°C on 20mV range.

INPUT RESISTANCE: 10MΩ.

MAX. ALLOWABLE INPUT: 1200V, limited to 10s below the 20V range.

NMRR: >60dB at 50Hz and 60Hz.

CMRR (1kΩ unbalance): >120dB at dc, 50Hz and 60Hz.

TRMS AC VOLTS

RANGE	RESOLUTION	179A ACCURACY[1]	177 ACCURACY[1]
200 mV	10 μV	0.7 + 15	0.5 + 15
2 V	100 μV	0.6 + 15	0.5 + 15
20 V	1 mV	0.5 + 15	0.5 + 15
200 V	10 mV	0.5 + 15	0.5 + 15
1000 V	100 mV	0.5 + 15	0.5 + 15

[1] Accuracy is specified for 1 year (above 2000 counts), 18°-28°C, 100Hz-10kHz, ±(%rdg + counts).

EXTENDED FREQUENCY ACCURACY (179A): 45Hz-100Hz: ±(0.7% + 15). **10kHz-20kHz:** ±(0.8% + 15) on 20V and higher ranges; ±(1.5% + 15) on 2V range; ±(2% + 15) on 200mV range. **(177): 45Hz-20kHz:** ±(0.7% + 15).

CREST FACTOR (ratio of peak value to rms value): 3:1.

MAX. ALLOWABLE INPUT VOLTAGE: 1000V rms, 1400V peak, 10^7V·Hz max.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-55°C), ±(%rdg +counts)/°C: **179A (45Hz-10kHz):** ±(0.07% + 2)/°C. **177 (45Hz-20kHz):** ±(0.05% + 2)/°C.

INPUT IMPEDANCE: 1MΩ shunted by <75pF.

CMRR (1kΩ unbalance): >60dB at dc, 50Hz and 60Hz.

DC & TRMS AC AMPS

		179A ACCURACY[1]		177 ACCURACY[1]	
RANGE	RESOLUTION	DC	AC[2]	DC[3]	AC[2]
20 μA	1 μA	—	—	0.2 + 2	—
200 μA	10 nA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
2 mA	100 nA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
20 mA	1 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
200 mA	10 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
2000 mA	100 μA	0.2 + 2	1 + 15	0.2 + 1	0.8 + 15
20 A	1 mA	0.5 + 2[4]	1 + 15[5]	—	—

[1] Accuracy specified for 1 year, 18°-28°C, ±(%rdg + counts).

[2] Ac accuracy is specified at 45Hz-10kHz, above 2000 counts.

[3] Front panel zero. [4] Add 0.1% rdg above 15A for self-heating. [5] ±1kHz max.

MAXIMUM INPUT: 2A, 250V dc or rms (fuse protected) except for 20A range on 179A: 15A continuous, 20A for 1 minute (unfused).

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C), ±(%rdg +counts)/°C: **179A:** DC: ±(0.01% + 0.2). AC: ±(0.07% + 2). **177:** DC: ±(0.01% + 0.2) except ±(0.01% + 0.6) on 20μA range. AC: ±(0.07 + 2).

MAXIMUM VOLTAGE BURDEN: 0.2V below 200mA range; 0.25V on 200mA range; 0.6V on 2000mA range; 0.5V on 20A range (179A).

OHMS

		MODEL 179A						MODEL 177		
		ACCURACY[1]		TEMPERATURE COEFFICIENT[2]		NOMINAL APPLIED CURRENT				
RANGE	RESOLUTION	HI Ω	LO Ω	HI Ω	LO Ω	HI Ω	LO Ω	ACCURACY[1]	TEMPERATURE COEFFICIENT[2]	NOMINAL APPLIED CURRENT
20 Ω[3]	1 mΩ	—	—	—	—	—	—	0.05 + 3	0.004 + 0.6	1 mA
200 Ω[3]	10 mΩ	—	—	—	—	—	—	0.05 + 2	0.004 + 0.2	1 mA
2 kΩ	100 mΩ	—	0.15 + 15	—	0.02 + 2	—	100 μA	0.04 + 1	0.004 + 0.2	1 mA
20 kΩ	1 Ω	0.04 + 1	0.15 + 15	0.003 + 0.2	0.02 + 2	100 μA	10 μA	0.04 + 1	0.004 + 0.2	100 μA
200 kΩ	10 Ω	0.04 + 1	0.15 + 15	0.003 + 0.2	0.02 + 2	10 μA	1 μA	0.04 + 1	0.004 + 0.2	10 μA
2000 kΩ	100 Ω	0.04 + 1	0.15 + 15	0.003 + 0.2	0.03 + 2	1 μA	0.1 μA	0.04 + 1	0.005 + 0.2	1 μA
20 MΩ	1 kΩ	0.10 + 1	—	0.02 + 0.2	—	0.1 μA	—	0.10 + 1	0.02 + 0.2	0.1 μA

[1] Accuracy specified for 1 year, 18°-28°C, ±(%rdg + digits). [2] Temperature coefficient specified for 0°-18°C and 28°-50°C, ±(%rdg + counts)/°C. [3] 177 front panel zero.

MAX. INPUT: 179A: 1kV dc or peak ac for 10s, 450V rms continuous. **177:** 350V peak.

MAXIMUM OPEN CIRCUIT VOLTAGE: 5V.

MAXIMUM VOLTAGE ACROSS UNKNOWN ON RANGE (179A): 2V on HI Ω, 0.2V on LO Ω.

GENERAL

DISPLAY: Five 0.5 in. LED digits w/decimal point and polarity indication.

CONVERSION PERIOD: 400ms.

OVERRANGE INDICATION: Display blinks all zeros above 19999 counts.

MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

ANALOG OUTPUT (177): Output Voltage: 1V = 10000 counts. **Output Resistance:** 5kΩ.

ENVIRONMENT: Operating: 0° to 55°C, 0 to 80% relative humidity up to 35°C. **Storage:** −25°C to +65°C.

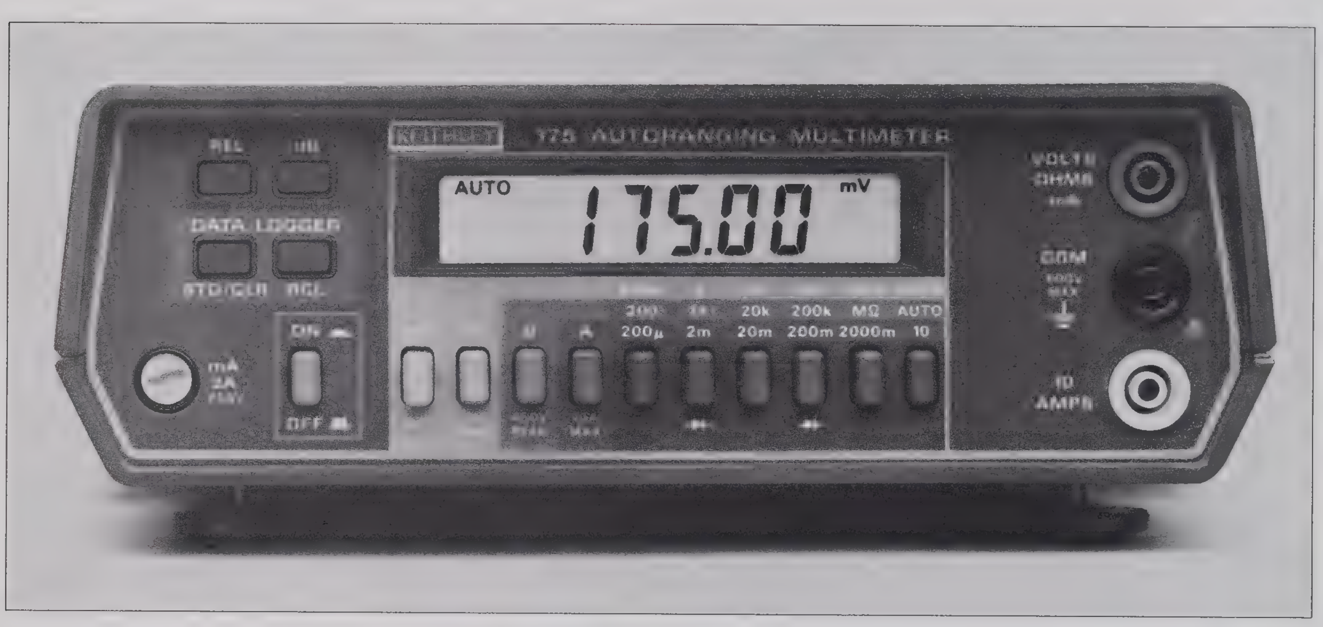
POWER: 105-125V or 210-250V (switch selected), 90-110V available. 50-60Hz, 5.5W (179A) or 8W (177). Optional 6-hour battery pack.

ACCESSORIES SUPPLIED: Instruction manual. 179A supplied with Model 1691 Test Leads.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

175/Digital Multimeter

4½ Digits, Autoranging


KEITHLEY
175 AUTORANGING MULTIMETER
REL
dB
DATA LOGGER
STO/CLR
RCL
AUTO
175.00
mV
20k
200k
MΩ
AUTO
200µ
2m
20m
200m
2000m
10
VOLTS
OHMS
COM
10
AMPS
ON
OFF

- **IEEE-488 interface option**
- **100 point data logger**
- **Digital calibration**
- **dB function**

The Keithley Model 175 is a 4½-digit LCD bench/portable DMM with 0.03% basic dcV accuracy. It offers extended measurement capabilities including a 10A current range, 100kHz bandwidth, and resistance measurements from 10mΩ to 200MΩ. Annunciators provide function, range, and feature indication.

With the Model 175, choose either manual or autoranging. Fast autoranging is available on dc volts, ohms, ac volts, and dB.

Data Logging. The Model 175's 100 point data logger is capable of storing data at six selectable rates from three readings per second to one every hour. Data can be recalled from the front panel. This feature enables collection of response curve data and monitoring of drifts or rates of change without the need for a printer.

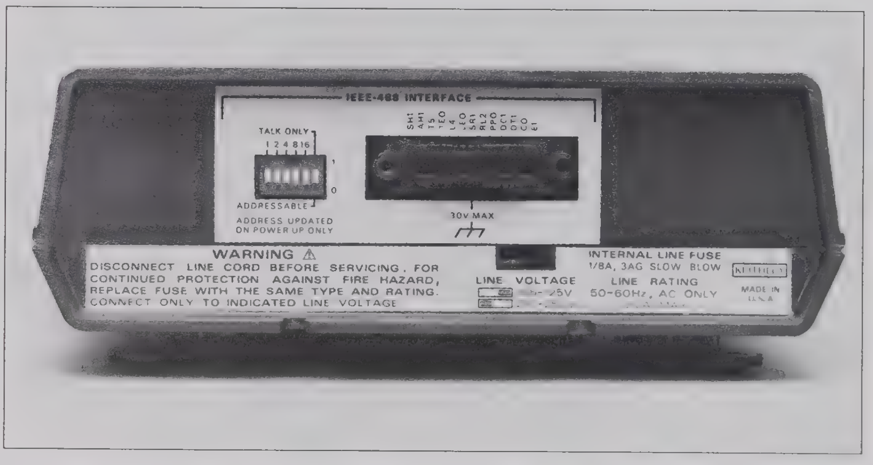
The Min/Max hold feature holds both lowest and highest readings over a selected period of time.

Relative Measurements. The dB function makes the Model 175 suitable for audio and communications applications. Direct dB readings are given throughout a dynamic range from −98 to +62dB, with 0.01dB resolution above 10mV. The 100kHz bandwidth covers well past the audio range. The optional rf probe extends the bandwidth to 250MHz.

The relative reference allows nulling out circuit voltage offsets or lead resistances. By nulling out power supply voltages or circuit outputs, drifts or changes can be displayed. Combined with the dB function, it can be used to make fast gain-stage measurements.

Digital Calibration. With the Model 175's digital calibration, all calibration factors are stored in non-volatile memory, allowing calibration to be done electronically without manual adjustments.

The IEEE-488 interface option offers range programmability on volts and ohms, TALK/LISTEN capability, trigger, SRQ, and other commands. Combined with the digital calibration feature, calibration can be performed on the bus in as little as two minutes.


IEEE-488 INTERFACE
TALK ONLY
1 2 4 8 16
ADDRESSABLE
ADDRESS UPDATED ON POWER UP ONLY
30V MAX
WARNING
DISCONNECT LINE CORD BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING. CONNECT ONLY TO INDICATED LINE VOLTAGE
LINE VOLTAGE
INTERNAL LINE FUSE
1/8A, 3AG SLOW BLOW
LINE RATING
50-60Hz, AC ONLY
KEITHLEY
MADE IN U.S.A.

Rear panel of the Model 175 Autoranging DMM shows line voltage selection switch and optional Model 1753 IEEE-488 Interface installed.

Digital Multimeter/175

4½ Digits, Autoranging

DC VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts)
200 mV	10 µV	0.03 + 2
2 V	100 µV	0.03 + 1
20 V	1 mV	0.03 + 1
200 V	10 mV	0.03 + 1
1000 V	100 mV	0.03 + 1

INPUT RESISTANCE: 11MΩ on 200mV, 2V, and 20V ranges. 10MΩ on 200V and 1000V ranges. (>1000MΩ on the 200mV and 2V ranges with all function buttons in the out position.

NORMAL MODE REJECTION RATIO: >60dB at 50Hz, 60Hz ±0.15%.

MAXIMUM ALLOWABLE INPUT: 1000V dc or peak ac (<10 seconds per minute on 200mV and 2V ranges; 300V rms continuous).

SETTLING TIME: 1 second to within 1 count of final reading on range.

dB MODE (ref: 600Ω): Accuracy: ±(0.02dB + 1 count) (above −78dBm). **Resolution:** 0.01dB above 5% of range.

TRMS AC VOLTS

RANGE	ACCURACY (1 Year)* 18°-28°C ±(%rdg+counts)				
	20Hz-50Hz	50Hz-10kHz	10kHz-20kHz	20kHz-50kHz	50kHz-100kHz
2V - 750V	1 + 20	0.5 + 20	1 + 40	2.5 + 75	5 + 200
200 mV	1 + 20	0.5 + 20	1.5 + 40	8 + 75	—

*Above 1800 counts.

MAXIMUM ALLOWABLE INPUT: 750V rms, 1000V peak (<10 seconds per minute on 200mV range; 300V rms continuous). 10^7V•Hz maximum.

3dB BANDWIDTH: 300kHz typical.

INPUT IMPEDANCE: 10MΩ paralleled by <75pF on 20V, 200V, and 1000V ranges. 11MΩ on 200mV and 2V ranges. Capacitively coupled.

SETTLING TIME: 2 seconds to within 15 counts of final reading on range.

dB MODE (ref: 600Ω):

RANGE	INPUT	ACCURACY (±dBm)			
		20Hz-10kHz	10kHz-20kHz	20kHz-50kHz	50kHz 100kHz
2V-750V	200 mV to 750 V (−12 to +59.8dBm)	0.2	0.26	0.56	1.2
200 mV	20 mV to 200 mV (−32 to −12 dBm)	0.2	0.3	1	—
	2 mV to 20 mV (−52 to −32 dBm)	2	3	—	—
	1 mV to 2 mV (−58 to −52 dBm)	2 *	—	—	—

Resolution: 0.01dB above 5% of range. *Up to 1kHz.

OHMS

RANGE		RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts)	MAX. VOLTAGE ACROSS UNKNOWN ON RANGE
200 Ω		10 mΩ	0.05 + 2*	0.2 V
2 kΩ	▶|	100 mΩ	0.05 + 1	2.0 V
20 kΩ		1 Ω	0.05 + 2	0.2 V
200 kΩ	▶|	10 Ω	0.05 + 1	2.0 V
2 MΩ*	MΩ**	100 Ω	0.05 + 2	0.2 V
20 MΩ*		1 kΩ	0.2 + 1	2.0 V
200 MΩ*		100 kΩ	2.0 + 1	2.0 V

*With zero set by REL function. **Appropriate range selected automatically.

MAXIMUM ALLOWABLE INPUT: 450V dc or peak ac.

OPEN-CIRCUIT VOLTAGE: +5V.

DIODE TEST: Display reads junction voltage up to 2V. Test current: 0.7mA nominal.

SETTLING TIME: 2 seconds to within 1 count of final reading on range.

DC AMPS

RANGE	RESOLUTION	MAXIMUM VOLTAGE BURDEN	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts)
200 µA	10 nA	0.3 V	0.15 + 2
2 mA	100 nA	0.3 V	0.15 + 2
20 mA	1 µA	0.3 V	0.15 + 2
200 mA	10 µA	0.3 V	0.2 + 2
2000 mA	100 µA	0.8 V	0.2 + 2
10 A	1 mA	0.3 V	0.75 + 2*

*Above 5A derate 0.15% rdg per amp for self-heating.

OVERLOAD PROTECTION: mA Input: 2A fuse (250V), externally accessible. **10A Input:** 20A for 15s, unfused.

SETTLING TIME: 1 second to within 1 count of final reading.

TRMS AC AMPS

RANGE	MAXIMUM VOLTTAGE BURDEN	ACCURACY (1 Year)* 18°-28°C ±(%rdg+counts)		
		20Hz-50Hz	50Hz-10kHz	10kHz-30kHz
200µA - 20mA	0.3 V	1 + 20	0.8 + 20	2 + 50
200 mA	0.3 V	1 + 20	0.8 + 20	—
2000 A	0.8 V	1 + 20	0.8 + 20	—
10 A	0.3 V	1.5 + 20**	1 + 20**	—

*Above 1800 counts. **1kHz max. Above 5A derate 0.15% rdg/amp for self-heating.

SETTLING TIME: 2 seconds to within 15 counts of final reading.

IEEE-488 BUS IMPLEMENTATION (Model 1753 Option)

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL2, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, REL, dB, EOI, Trigger, Calibration, SRQ, Status, Output Format, Terminator.

GENERAL

DISPLAY: 4½-digit LCD, 0.5 in. height; polarity, function, range, and status indication.

RANGING: Auto or manual on dc volts, ac volts, ohms; manual on ac amps, dc amps.

AUTORANGING TIME: 300ms per range.

RELATIVE: Pushbutton allows zeroing of on range readings. Allows readings to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATA LOGGER and MIN/MAX: 100 reading storage capacity; records data at one of six selectable rates from 3 rdg/s to 1 rdg/hr. Also detects and stores maximum and minimum readings continuously in data logger mode.

CONVERSION RATE: 3 readings per second.

OVERRANGE INDICATION: "OL" displayed.

CREST FACTOR (ratio of peak value to rms value), AC FUNCTIONS: 3.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

COMMON MODE REJECTION RATIO (1kΩ unbalance): >120dB at dc, 50Hz, 60Hz ±0.15%. >60dB in ac volts.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.1×applicable accuracy speciifcation)/°C except ±(0.07%+2)/°C for 50Hz-10kHz in ac volts.

ENVIRONMENT: Operating: 0° to 50°C; <80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35° to 50°C. **Storage:** −25° to +60°C.

POWER: 105-125V or 210-250V (external switch selected), 90-110V available; 50-60Hz, 12VA. Optional 6-hour battery pack, Model 1758.

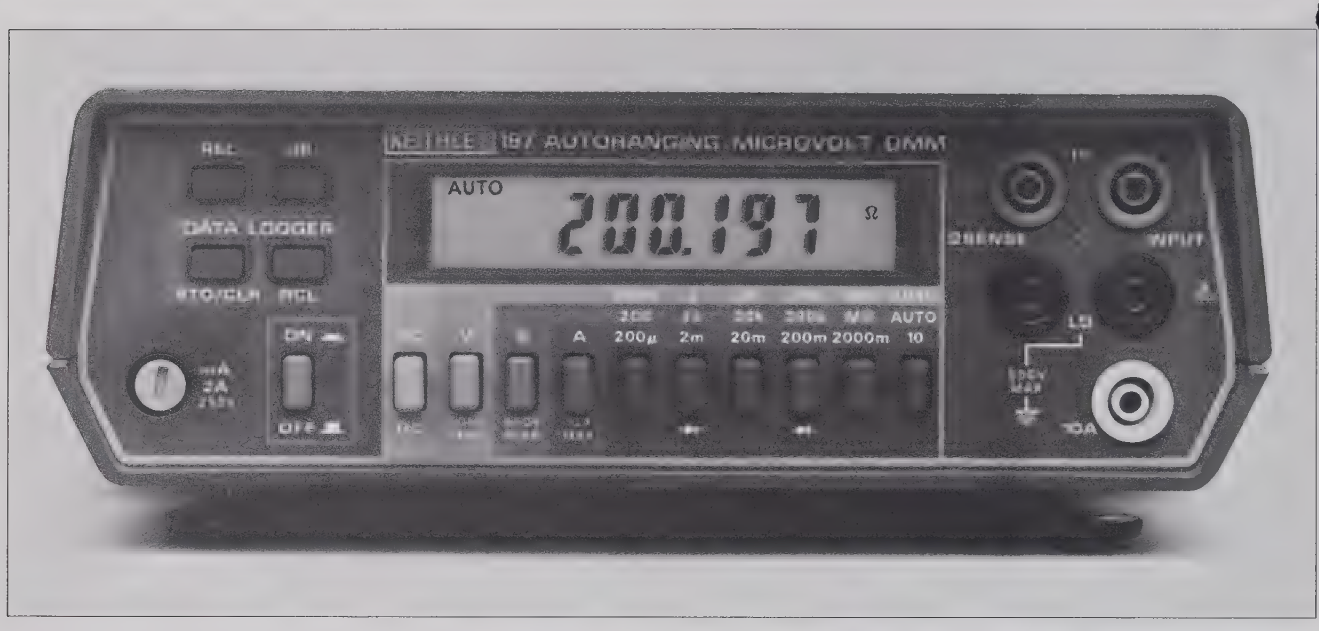
DIMENSIONS, WEIGHT: 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (3 lbs., 14 oz.).

ACCESSORIES SUPPLIED: Model 1751 Shrouded Test Leads, instruction manual.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

197/Digital Multimeter

5½ Digits, Microvolt Sensitivity


KEITHLEY 197 AUTORANGING MICROVOLT DMM
AUTO
200.197
Ω
DATA LOGGER
AUTO
200µ
2m
20m
200m
2000m
10
A
INPUT
10A

- **1µV, 1mΩ, 1nA sensitivity**
- **TRMS ac measurements to 100kHz**
- **Data logger, relative reference, dB**
- **Analog and IEEE-488 output option**

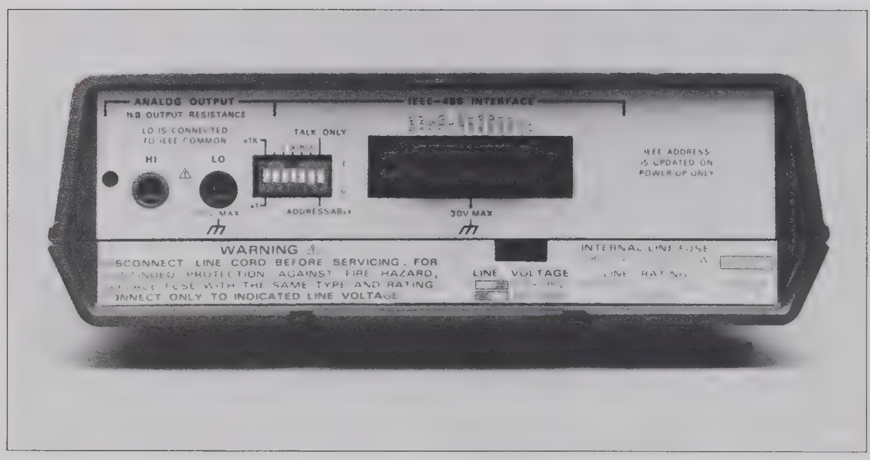
The Model 197 combines 5½-digit resolution (on a 220,000-count display) with 1µV, 1nA, 1mΩ sensitivity Basic dcV accuracy is 0.011%.

Extended Performance. Measure voltage over 9 decades from 1µV to 1000V. Input resistance on the two lowest voltage ranges exceeds 1GΩ. TRMS ac measurements can be made to 100kHz. Make 2- or 4- terminal ohms measurements over 11 decades from 1mΩ to 220MΩ. Six current ranges measure from 1nA to 10A.

The microprocessor-based 197 is loaded with smart features. Display annunciators indicate the measurement mode and units. Autoranging on V, Ω, and dB automatically displays maximum resolution.

dB Ranges. Audio and communication circuit analysis is easy with direct-reading dB measurements referenced to 600Ω. Resolution is 0.01dB above 1mV.

Pushbutton relative reference (REL) nulls out or zeros on-range readings. REL can also null out circuit voltage offsets or lead resistances and create a new baseline for differential measurements. REL works with the dB function to reference measurements to resistances other than 600Ω or to make convenient amplifier stage gain comparisons.


ANALOG OUTPUT
1kΩ OUTPUT RESISTANCE
LO IS CONNECTED TO IEEE COMMON
HI
LO
TALK ONLY
ADDRESSABLE
IEEE-488 INTERFACE
IEEE ADDRESS IS UPDATED ON POWER-UP ONLY
30V MAX
WARNING
LINE VOLTAGE
INTERNAL LINE FUSE

Rear panel of 197; note line voltage selection switch and installed Model 1972 Analog/IEEE-488 Output option.

The DATA LOGGER stores up to 100 readings at 6 automatic rates from 3 per second to 1 per hour, or manually at the touch of a button. Minimum and maximum readings are continuously updated (3 per second) in the DATA LOGGER mode.

Digital Calibration. Calibration factors for each range are stored in a non-volatile RAM. Without potentiometers to adjust, repeatable calibration is fast and easy.

Powerful Options. Combine IEEE-488 interface with real-time analog monitoring with the 1972 Analog/IEEE Output option. The TALK/LISTEN interface has range programmability on volts and ohms. The smart features, dB, REL, digital calibration, and DATA LOGGER are available over the bus. The analog output has selectable gain of ×1 or ×1000. The REL feature zeros the analog output as well as the display. The IEEE-488 interface alone is also available as the 1973 option.

The 1978 battery pack option enables data to be collected in the field with the DATA LOGGER and processed back in the lab by transferring the data to an IEEE-compatible printer.

Digital Multimeter/197

5½ Digits, Microvolt Sensitivity

DC VOLTS

RANGE	RESO-LUTION	INPUT RESISTANCE	ACCURACY ±(%rdg+counts) 24 Hr.,* 22°-24°C	ACCURACY ±(%rdg+counts) 1 Year, 18°-28°C
200 mV	1 μV	>1 GΩ	0.007 + 2**	0.016 + 3**
2 V	10 μV	>1 GΩ	0.005 + 2	0.011 + 2
20 V	100 μV	11 MΩ	0.006 + 2	0.015 + 3
200 V	1 mV	10 MΩ	0.006 + 2	0.015 + 2
1000 V	10 mV	10 MΩ	0.007 + 2	0.015 + 2

*Relative to calibration accuracy. **When properly zeroed.

NMRR: >60dB at 50Hz, 60Hz ±0.1%.

MAXIMUM ALLOWABLE INPUT: 1000V dc or peak ac (<10 seconds per minute on 200mV and 2V ranges; 300V rms contiunous).

SETTLING TIME: 1 second to within 3 counts of final reading on range.

dB MODE (ref: 600Ω): Accuracy: ±(0.02dB+1 count) above −78dBm. **Resolution:** 0.01dB above 0.5% of range.

TRMS AC VOLTS

RANGE	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts) 20Hz - 50Hz*	50Hz - 10kHz*	10kHz - 20kHz*	20kHz - 50kHz**	50kHz - 100kHz**
200 mV	1.00 + 100	0.35 + 100	0.6 + 200	1.5 + 250	5 + 400
2V - 200V	1.00 + 100	0.35 + 100	0.6 + 200	1.5 + 250	3 + 400
750 V	1.25 + 100	0.75 + 100	1.0 + 200	1.8 + 250	3 + 400

*Above 1800 counts. **Above 18000 counts.

MAXIMUM ALLOWABLE INPUT: 750V rms, 1000V peak (<10 seconds per minute on 200mV and 2V ranges; 300V rms continuous). 10^7V•Hz maximum.

3dB BANDWIDTH: 300kHz typical.

INPUT IMPEDANCE: 1MΩ paralleled by <75pF on 200V and 750V ranges; 1.1MΩ on 200mV, 2V, and 20V ranges. Capacitively coupled.

SETTLING TIME: 1 second to within 0.1% of final reading on range.

dB MODE (ref: 600Ω):

RANGE	INPUT	ACCURACY (±dBm) 20Hz - 10kHz	10kHz - 20kHz	20kHz - 50kHz	50kHz - 100kHz
2V - 750V	200 mV to 750 V (−12 to 59.8dBm)	0.18	0.18	0.28	0.50
200 mV	20 mV to 200 mV (−32 to −12dBm)	0.18	0.18	0.28	0.65
	2 mV to 20 mV (−52 to −32dBm)	0.85	1.10	2.00	—
	1 mV to 2 mV (−58 to −52dBm)	2.00	3.00	—	—

Resolution: 0.01dBm above 0.5% of range.

DC AMPS

RANGE	RESOLUTION	MAXIMUM VOLTAGE BURDEN	ACCURACY (1 Yr.) 18°-28°C ±(%rdg+counts)
200 μA	1 nA	0.3 V	0.1 + 15
2 mA	10 nA	0.3 V	0.1 + 15
20 mA	100 nA	0.3 V	0.1 + 15
200 mA	1 μA	0.3 V	0.2 + 15
2000 mA	10 μA	0.8 V	0.2 + 15
10 A	100 μA	0.3 V	0.75 + 15*

*Above 5A derate 0.15% rdg per amp for self-heating.

OVERLOAD PROTECTION: mA Input: 2A fuse (250V), externally accessible. **10A Input:** 20A for 15s, unfused.

SETTLING TIME: 1 second to within 3 counts of final reading.

TRMS AC AMPS

RANGE	MAXIMUM VOLTAGE BURDEN	ACCURACY (1 Year)* 18°-28°C ±(%rdg+counts) 20Hz - 50Hz	50Hz - 10kHz	10kHz - 30kHz
200μA - 20mA	0.3 V	1.0 + 100	0.8 + 100	2 + 250
200 mA	0.3 V	1.0 + 100	0.8 + 100	—
2000 mA	0.8 V	1.0 + 100	0.8 + 100	—
10 A	0.3 V	1.5 + 100	1.0 + 100**	—

*Above 1800 counts. **1kHz max. Above 5A derate 0.15% rdg/amp for self-heating.

SETTLING TIME: 1 second to within 0.1% of final reading.

OHMS

RANGE	RESO-LUTION	OUTPUT NOMINAL I-SHORT	OUTPUT MAX. V ACROSS UNKNOWN	ACCURACY ±(%rdg+counts) 24 Hr., 22°-24°C	ACCURACY ±(%rdg+counts) 1 Year, 18°-28°C
200 Ω	1 mΩ	2 mA	0.5 V	0.01 + 2*	0.018 + 3*
2 kΩ ▶|	10 mΩ	2 mA	4.0 V	0.01 + 2	0.018 + 2
20 kΩ	100 mΩ	400 μA	4.0 V	0.014 + 2	0.026 + 2
200 kΩ ▶|	1 Ω	40 μA	4.0 V	0.014 + 2	0.026 + 2
2 MΩ **	1 Ω	4 μA	4.0 V	0.02 + 2	0.035 + 2
20 MΩ **	1 Ω	400 nA	4.0 V	0.10 + 2	0.12 + 2
200 MΩ **	10 kΩ	400 nA	5.0 V	2.00 + 1	2.00 + 1

*When properly zeroed. **Appropriate range selected automatically in MΩ.

CONFIGURATION: Automatic 2- or 4-terminal.

MAXIMUM ALLOWABLE INPUT: 450V dc or peak ac 10 seconds per minute. 350V rms continuous.

OPEN CIRCUIT VOLTAGE: +5V.

DIODE TEST: Display reads junction voltage up to 2.2V. **Test Current:** 1.6mA nominal.

SETTLING TIME: 2 seconds to within 3 counts of final reading on range.

ANALOG/IEEE OUTPUT (Model 1972 Option)

ANALOG OUTPUT:

Accuracy: ±(0.25% of displayed reading + 2mV).

Response Time: Follows display conversion rate.

Level: 1V = 100,000 counts on ×1 gain. 1V = 100 counts on ×1000 gain. Maximum output voltage = 4V.

Output Resistance: 1000Ω.

Isolation: 500V peak, Input LO to Output LO. 30V peak, output LO to earth ground.

IEEE OUTPUT: See IEEE BUS IMPLEMENTATION.

IEEE BUS IMPLEMENTATION (1972 Analog/IEEE & 1973 IEEE Options)

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, REL, dB, EOI, Trigger, Calibration, SRQ, Status, Output Format, Terminator, Data Logger Retrieval.

GENERAL

DISPLAY: ±220,000 count LCD, 0.45 in. height; polarity, function, range, and status indication.

RANGING: Auto or manual on dc volts, ac volts, and ohms; manual on ac amps and dc amps.

AUTORANGING TIME: 300ms per range average.

RELATIVE: Pushbutton allows zeroing of on range readings. Allows readings to to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATA LOGGER and MIN/MAX: 100 reading storage capacity; records data at one of six selectable rates from 3 readings/second to 1 reading/hour or by manual triggering. Also detects and stores maximum and minimum readings continuously while in data logger mode.

CONVERSION RATE: 3 readings/second.

OVERRANGE INDICATION: "OL" displayed.

CREST FACTOR (ratio of peak value to rms value), AC FUNCTIONS: 3.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

COMMON MODE REJECTION RATIO (1kΩ unbalance): >120dB at dc, 50Hz, 60Hz ±0.1%. >60dB in ac volts.

TEMPARATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.1×applicable one year accuracy specification)/°C.

ENVIRONMENT: Operating: 0°-50°C; <80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°-50°C. **Storage:** −25° to 60°C.

WARMUP: 1 hour to rated accuracy.

POWER: 105-125V or 210-250V (external switch selected), 90-110V available; 50-60Hz, 12VA. Optional 5-hour battery pack, Model 1978.

DIMENSIONS, WEIGHT: 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (3 lbs., 14 oz.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, instruction manual.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

195A/Digital Multimeter

System/Bench

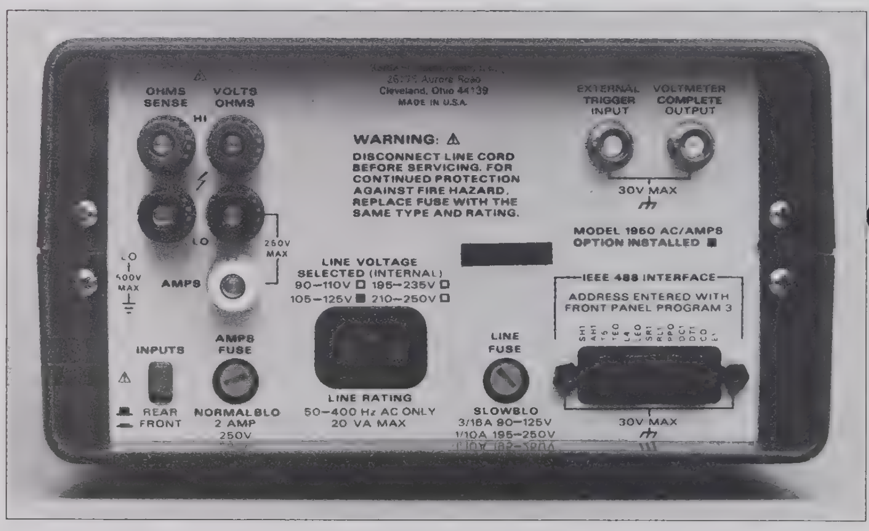
- **100nV, 100pA, 100μΩ, 0.01°C or °F sensitivities**
- **Direct reading temperature**
- **100-reading data buffer**
- **Trigger IN/OUT**
- **Autoranging current**

The Model 195A gives you Keithley sensitivity and versatility across six full functions. With the basic unit, you measure dc volts, automatic 2- or 4-wire ohms, and temperature (°C or °F). You can measure temperature accurately, using any 3- or 4-wire 100Ω RTD. Sensor current of <1mA rms minimizes self-heating error. With the Option 1950, you add TRMS ac volts, dc amps, and TRMS ac amps functions.

The Model 195A has outstanding sensitivity, including much more (100pA) in current than other 5½-digit DMMs. In addition, dc current can be measured on six ranges for maximum resolution.

The IEEE-488 bus interface is standard, and all functions are programmable. With front and rear inputs, External Trigger input, and Voltmeter (reading) Complete output, the 195A has all the capabilities to be a versatile measurement instrument in an IEEE-488 test system. Furthermore, the 100-reading buffer, combined with trigger control, enables the 195A to take automated measurements with or without a system controller.

KEITHLEY
195A DIGITAL MULTIMETER
195.000 ÷ 1
TALK
LISTEN
REMOTE
OHMS SENSE
VOLTS OHMS
HI
POWER
PROGRAM
PRGM
RECALL
ENT
AMPS
TEMP


OHMS SENSE
VOLTS OHMS
HI
LO
250V MAX
500V MAX
AMPS
INPUTS
REAR
FRONT
AMPS FUSE
NORMALBLO 2 AMP 250V
Cleveland, Ohio 44139
MADE IN U.S.A.
WARNING:
DISCONNECT LINE CORD BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING.
LINE VOLTAGE SELECTED (INTERNAL)
90–110V ☐ 195–235V ☐
105–125V ■ 210–250V ☐
LINE RATING
50–400 Hz AC ONLY
20 VA MAX
LINE FUSE
SLOWBLO
3/16A 90–125V
1/10A 195–250V
EXTERNAL TRIGGER INPUT
VOLTMETER COMPLETE OUTPUT
30V MAX
MODEL 1950 AC/AMPS OPTION INSTALLED ■
IEEE 488 INTERFACE
ADDRESS ENTERED WITH FRONT PANEL PROGRAM 3
30V MAX

Rear panel of Model 195A features EXTERNAL TRIGGER input, VOLTMETER COMPLETE output, built-in IEEE-488 interface, and switch-selected rear inputs.

FRONT PANEL PROGRAMS

NO.	NAME	DESCRIPTION
0	CLEAR	Cancels program mode.
1	NON-VOLATILE RAM STORAGE	Stores programs 3, 4, 5, and 8 data in NVRAM.
2	MULTIPLEX	Defeats input amplifier multiplexing.
3	IEEE BUS MODE	ADDRESSABLE and TALK ONLY entry.
4	LINE FREQUENCY	Selects 50Hz or 60Hz operation.
5	CALIBRATION	Performs digital calibration.
6	EXTENDED PROGRAMS	Enables entry to optional expansion programs.
7	DATA LOGGER	Allows 100-reading storage at 9 programmable rates; also stores highest, lowest, and average reading.
8	DIAGNOSTICS	Troubleshooting aid and self-test.
9	TRIGGER	Enables front panel or external triggering.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Averaging, EOI, Trigger, Terminator, Filter, Delay, 100-Reading Storage, Calibration, Display, Multiplex Off, Status, Service Request, Self Test, Output Format.

CONVERSION RATES (DC VOLTS):

USABLE RESOLUTION	INTEGRATION PERIOD	TRIGGER TO FIRST BYTE OUT	MAXIMUM READING RATE*
3½-Digit	3.3 ms	17ms	76
4½-Digit	16.66ms**	30ms	36
5½-Digit	100 ms	114ms	9

*Readings/second. **20ms at 50Hz.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

PROGRAMMABLE SRQ MODES: SRQ On/Off. SRQ available on Reading Done, Overflow, Illegal DDC, Illegal DDC Option, Buffer Full, Buffer ½ Full, Self Test Failed, and Trigger Overrun.

STATUS: Transfers current instrument setup including model number over the bus.

DC VOLTS (5½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY* ±(%rdg+counts) 24 Hr., 23° ±1°C	ACCURACY* ±(%rdg+counts) 1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C
20 mV	100 nV	>1 GΩ	0.01+40	0.025+40	0.003 + 2
200 mV	1 μV	>1 GΩ	0.01+ 6	0.025+ 6	0.003 + 0.5
2 V	10 μV	>1 GΩ	0.01+ 8	0.025+ 8	0.003 + 0.5
20 V	100 μV	10 MΩ	0.01+ 6	0.025+ 6	0.003 + 0.5
200 V	1 mV	10 MΩ	0.01+ 8	0.025+ 8	0.003 + 0.5
1000 V	10 mV	10 MΩ	0.01+ 6	0.025+ 6	0.003 + 0.5

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20mV range after zeroing).

NMRR: >60dB at 50 or 60Hz.

CMRR: >120dB at dc and 50 or 60Hz (with 1kΩ in either lead).

MAXIMUM ALLOWABLE INPUT: 1000V peak.

BENCH READING RATE: 5 readings/second.

OHMS (5½ Digits)

RANGE	RESOLUTION	OUTPUT I short	OUTPUT Vopen	ACCURACY* ±(%rdg+counts) 24 Hr., 23° ±1°C	ACCURACY* ±(%rdg+counts) 1 Yr., 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C
20 Ω	100 μΩ	– 2 mA	–2 V	0.015+25	0.025+25	0.003 + 2
200 Ω	1 mΩ	– 2 mA	–2 V	0.015+ 7	0.025+ 7	0.003 + 0.5
2 kΩ	10 mΩ	– 2 mA	–2 V	0.015+ 5	0.022+ 5	0.003 + 0.5
20 kΩ	100 mΩ	– 20 μA	–2 V	0.015+ 7	0.025+ 7	0.003 + 0.5
200 kΩ	1 Ω	– 20 μA	–2 V	0.015+ 5	0.022+ 5	0.003 + 0.5
2 MΩ	10 Ω	–200 nA	–2 V	0.03 + 7	0.050+ 7	0.015 + 1
20 MΩ	100 Ω	–200 nA	–2 V	0.06 + 5	0.100+ 5	0.025 + 1

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20Ω range after zeroing).

TRMS AC VOLTS Option 1950 (5½ Digits)

RANGE	RESOLUTION	ACCURACY (1 Year)* ±(%rdg+counts) 18°-28°C 20Hz-45Hz	45Hz-10kHz	10kHz-20kHz	20kHz-50kHz
200 mV**	1 μV	0.8 + 200	0.3 + 200	0.7 + 200	2.0 + 300
2 V	10 μV	0.8 + 200	0.3 + 200	0.7 + 200	2.0 + 250
20 V	100 μV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250
200 V	1 mV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250
700 V	10 mV	0.8 + 200	0.3 + 200	0.7 + 200	1.5 + 250

*In 4½-digit mode, divide count error by 10. **Above 1mV.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): < ±(0.1×applicable accuracy specification)/°C.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

INPUT IMPEDANCE: 2MΩ shunted by <75pF.

MAXIMUM ALLOWABLE INPUT: 1000V peak, 10^7V•Hz.

BENCH READING RATE: 3 readings/second.

CMRR: >60dB at dc, 50 or 60Hz (with 1kΩ in either lead).

BANDWIDTH: –3dB at 250kHz typical.

DC AMPS Option 1950 (5½ Digits)

RANGE	RESOLUTION	ACCURACY* (1 Year) ±(%rdg+counts) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C	MAXIMUM VOLTAGE BURDEN
20 μA	100 pA	0.14 + 40**	0.01 + 2	0.03 V
200 μA	1 nA	0.09 + 10	0.01 + 0.5	0.25 V
2 mA	10 nA	0.09 + 10	0.01 + 0.5	0.25 V
20 mA	100 nA	0.09 + 10	0.01 + 0.5	0.25 V
200 mA	1 μA	0.09 + 10	0.01 + 0.5	0.28 V
2 A	10 μA	0.09 + 10	0.01 + 0.5	1 V

*After pushbutton or bus zeroing. In 4½-digit mode, counts = ±2 (except ±4 on 20μA range after zeroing).

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

BENCH READING RATE: 5 readings/second.

TRMS AC AMPS Option 1950 (5½ Digits)

RANGE	RESOLUTION	ACCURACY* (1 Year) ±(%rdg+counts) 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C	MAXIMUM VOLTAGE BURDEN
200 μA	1 nA	0.6 + 250	0.04 + 10	0.25 V
2 mA	10 nA	0.6 + 250	0.04 + 10	0.25 V
20 mA	100 nA	0.6 + 250	0.04 + 10	0.25 V
200 mA	1 μA	0.6 + 250	0.04 + 10	0.28 V
2 A	10 μA	0.6 + 250	0.04 + 10	1 V

*Above 0.5% of range. In 4½-digit mode, divide count error by 10.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

OVERLOAD PROTECTION: 2A fuse (250V), externally accessible.

BENCH READING RATE: 3 readings/second.

TEMPERATURE

SPAN	RESOLUTION	4-WIRE ACCURACY* ±(%rdg+counts) 1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg+counts)/°C 0°-18°C & 28°-50°C
C°			
–200.00° to 230.00°	0.01°	0.03 + 10	0.003 + 0.4
230.00° to 630.00°	0.01°	0.03 + 40	0.003 + 4
–230.00° to –200.00°	0.01°	0.03 + 40	0.003 + 4
°F			
–328.00° to 446.00°	0.01°	0.03 + 18	0.003 + 0.7
446.00° to 1100.00°	0.01°	0.03 + 72	0.003 + 7
–360.00° to –328.00°	0.01°	0.03 + 72	0.003 + 7

*Autorange mode, excluding probe errors.

RTD TYPE: 100Ω platinum; DIN 43 760 or IPTS-68, programmable alpha and delta, 3- or 4-wire.

MAXIMUM LEAD RESISTANCE (each lead): 4-wire: 25Ω; 3-wire: 15Ω.

SENSOR CURRENT: 1.0mA maximum, rms.

BENCH READING RATE: 1.2reading/second.

MAXIMUM COMMON MODE VOLTAGE: 500V (42V with Model 1951 connected).

COMMON MODE REJECTION: <0.005°C/V at dc, 50Hz and 60Hz (100Ω unbalance, LO driven).

MAXIMUM ALLOWABLE INPUT: 360V peak, 250V rms.

GENERAL

DISPLAY: Six 0.5 in. LED digits with decimal point, exponent, and polarity. Function and IEEE bus status also displayed.

RANGING: Manual or fast autoranging (150ms/range change on dc volts).

ISOLATION: Input LO to IEEE LO or power line ground: 500V max., 5×10^5V•Hz; >10^9Ω paralleled by 300pF.

WARMUP: 1 hour to rated accuracy.

OPERATING ENVIRONMENT: 0°-50°C, 0% to 80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: –25° to 65°C.

POWER: 105-125V or 210-250V (internal switch selected), 50Hz to 400Hz, 24VA maximum. 90-110V & 180-220V versions available upon request.

CONNECTORS: Analog: Switch selectable front or rear, 5-way gold plated binding posts. **Digital:** Trigger input and Voltmeter Complete output on rear panel: BNCs.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.2kg (7 lbs.).

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

196/System DMM

System/Bench

- **6½ digit resolution in V, Ω**
- **100nV, 100μΩ, 1nA sensitivities**
- **Up to 1000 readings/second**
- **Offset compensated Ω**
- **Non-volatile TRANSLATOR software**

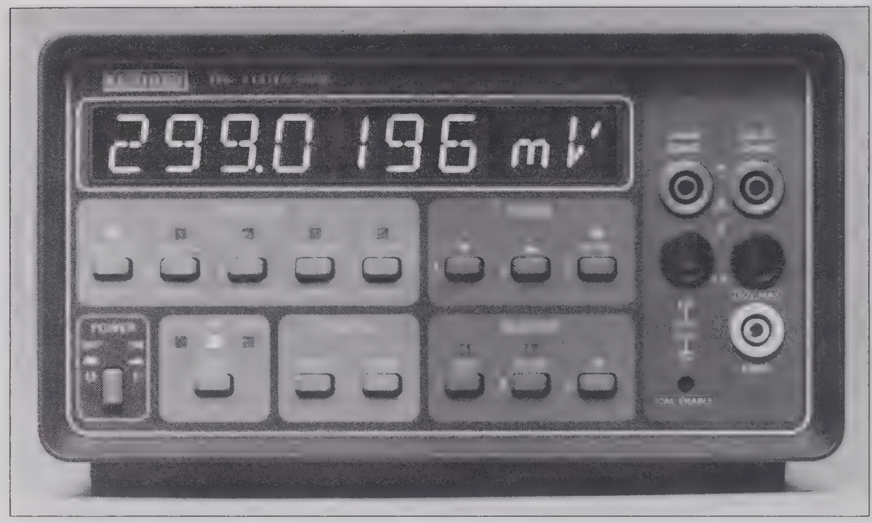
The fully IEEE-488 programmable Model 196 System DMM packages high resolution, high sensitivity, and high measurement speed into a compact half-rack enclosure. All five basic functions (dcV, acV, dcA, acA, and ohms) as well as programmability are standard.

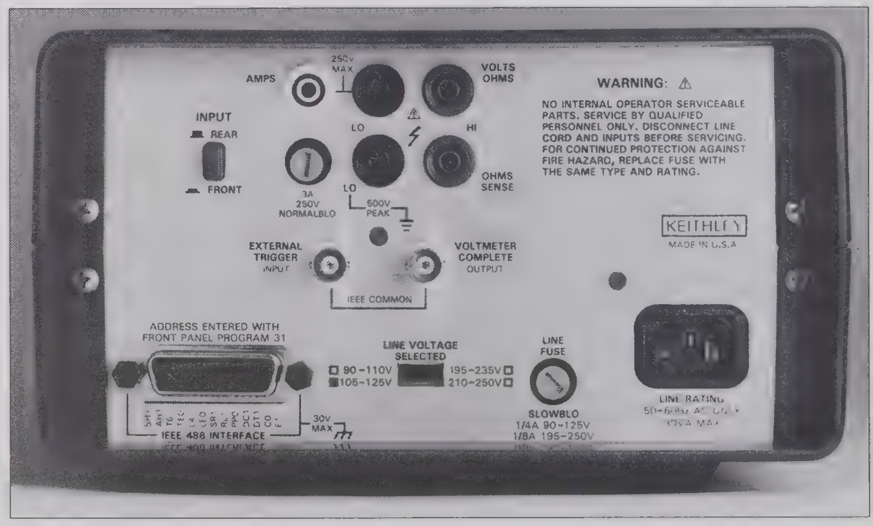
Resolve 1/3 ppm. Whether you are developing and testing the next generation of components which have tighter tolerances and increased sensitivities, or you are researching a low level phenomenon, you need higher levels of both resolution and sensitivity in your DMM. The Model 196 meets your needs with a 6½-digit, 3,000,000 count display. At full scale the last digit represents a very small 1/3 ppm.

Detect Small Changes. The 196 provides excellent sensitivity in not only voltage and resistance but also current. Combined with the 3,000,000 count display, you can, for example, resolve 1μV in 3 volts, 1mΩ in 3kΩ, and 10nA in 3mA. In addition to the high resolution, basic 90-day dcV accuracy is 30ppm.

Enhance Measurement Quality. Special features enable you to obtain the most from the 196's resolution and sensitivity. Eliminate thermal effects that can create errors in low level resistance measurements with a measurement technique called *offset compensated ohms*. Control the user-programmable digital filtering levels to compensate for external noise. Eliminate offsets with the user-programmable ZERO function. In fact, independent zero and filter levels can be established for each function; the 196 stores these parameters separately.

High Speed for High System Throughput. When speed is more critical than extracting maximum resolution and sensitivity, the 196 has the versatility to meet your needs. Capture low frequency phenomena of any waveshape with a measurement rate of 1000 readings/second at 3½-digit resolution. At 4½-digit resolution acquire 333 readings/second. In system applications the 196 can be triggered to take 200 readings/second at 3½ digits. When reading speeds exceed the rate at which they can be handled over the IEEE-488 bus, readings can be stored in the 196's 500-reading buffer.




AMPS
250V MAX
VOLTS OHMS
WARNING: ⚠
NO INTERNAL OPERATOR SERVICEABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD AND INPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING.
INPUT
REAR
FRONT
LO
HI
LO
OHMS SENSE
3A 250V NORMALBLO
500V PEAK
KEITHLEY
MADE IN U.S.A
EXTERNAL TRIGGER INPUT
VOLTMETER COMPLETE OUTPUT
IEEE COMMON
ADDRESS ENTERED WITH FRONT PANEL PROGRAM 31
LINE VOLTAGE SELECTED
90-110V
105-125V
195-235V
210-250V
LINE FUSE
30V MAX
IEEE 488 INTERFACE
SLOWBLO
1/4A 90-125V
1/8A 195-250V
LINE RATING

Rear panel of Model 196 features front/rear input selection switch, external trigger input, voltmeter complete output, and IEEE-488 interface connector.

Eases the System Integration Task. Simplicity in programming and consistency in operation are inherent in Keithley's IEEE-488 implementation.

Keithley's exclusive TRANSLATOR software enables you to substitute your own mnemonics for the 196's device-dependent command strings. The mnemonics use fewer characters, making your code more readable and reducing bus activity. TRANSLATOR also provides emulation capability which lets you upgrade your system by using the 196 to replace an older DMM without making major changes to the main body of your software. The TRANSLATOR commands are retained in non-volatile memory, so the 196 needs to be programmed only once.

System DMM/196

DC VOLTS

(6½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY[1] ±(%rdg + counts) 24 Hr.,[2] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg +counts)/°C 0°-18° & 28°-50°C
300 mV	100 nV	>1 GΩ	0.0020 + 20[3]	0.005 + 20[3]	0.008 + 20[3]	0.0006 + 10
3 V	1 µV	>1 GΩ	0.0013 + 10	0.003 + 20	0.0038 + 20	0.0004 + 1
30 V	10 µV	11 MΩ	0.0015 + 10	0.006 + 20	0.008 + 30	0.0013 + 3
300 V	100 µV	10.1 MΩ	0.003 + 10	0.009 + 20	0.009 + 30	0.0013 + 1

[1] For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300mV range). For 3½-digit accuracy, count error is 5.

[2] Relative to calibration standards.

[3] When properly zeroed.

ANALOG SETTLING TIME: <1ms (<2ms on 300mV range), to 0.01% of step change.

CMRR: >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 10ppm of range for 3V-300V ranges; 15ppm of range for 300mV range; at 23°C ±1°C.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

TRMS AC VOLTS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20Hz-50Hz[2]	50Hz-200Hz[2]	200Hz-10kHz[2]	10kHz-20kHz[2]	20kHz-100kHz[3]
300 mV	1 µV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	2.0 + 300
3 V	10 µV	2 + 100	0.3 + 100	0.15 + 100	0.3 + 200	1.5 + 300
30 V	100 µV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300

[1] For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for inputs >200Hz.

[2] For sinewave inputs >2,000 counts.

[3] For sinewave inputs >20,000 counts.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NONSINUSOIDAL INPUTS: For fundamental frequencies <1kHz, crest factor <3, add 0.25% of reading to specified accuracy for 300mV and 3V ranges; add 0.6% of reading to specified accuracy for 30V and 300V ranges.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

3dB BANDWIDTH: 300kHz typical.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, 10^7 V·Hz, whichever is less.

SETTLING TIME: 1 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C below 20kHz, ±(0.2x) for 20kHz to 100kHz.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

dB (Ref. = 1V):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-20kHz	20kHz-100kHz	RESOLUTION
−34 to +49 dB (20mV to 300V)	0.2	0.4	0.01 dB
−54 to −34 dB (2mV to 20mV)	1.1	3[1]	0.01 dB

[1] Typical.

OHMS

(6½ Digits)

RANGE	RESOLUTION	NOMINAL I-SHORT	ACCURACY[1] ±(%rdg +counts) 24 Hr.,[5] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18° & 28°-50°C
300 Ω[2]	100 µΩ	1.7 mA	0.0025 + 20[3]	0.008 + 20[3]	0.010 + 20[3]	0.001 + 7
3 kΩ[2]	1 mΩ	1.7 mA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
30 kΩ[2]	10 mΩ	160 µA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
300 kΩ	100 mΩ	50 µA	0.006 + 20	0.020 + 20	0.021 + 20	0.004 + 1
3 MΩ	1 Ω	5 µA	0.007 + 20	0.020 + 20	0.021 + 20	0.004 + 1
30 MΩ	10 Ω	0.5 µA	0.06 + 50	0.1 + 50	0.1 + 50	0.030 + 1
300 MΩ[4]	1 kΩ	0.5 µA	2.0 + 5	2.0 + 5	2.0 + 5	0.30 + 1

[1] For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range). For 3½-digit accuracy, count error is 5.

[2] 4-wire accuracy, 300Ω-30kΩ ranges.

[3] When properly zeroed.

[4] Resolution on 300MΩ range is limited to 5½ digits.

[5] Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire. Offset compensation available on 300Ω-30kΩ ranges, requires proper zeroing. Allowable compensation of ±10mV on 300Ω range and ±100mV on 3kΩ and 30kΩ ranges.

MAX. ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: 5.5V maximum.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 300Ω-30kΩ ranges, at 23°C ±1°C.

196/System DMM

System/Bench

DC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg +counts) 1 Year, 18°-28°C	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	0.09 + 20	0.4 V
3 mA	10 nA	0.05 + 10	0.4 V
30 mA	100 nA	0.05 + 10	0.4 V
300 mA	1 μA	0.05 + 10	0.5 V
3 A	10 μA	0.09 + 10	2 V

[1] 4½-digit count error is 20. 3½-digit count error is 5.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V), accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C.

TRMS AC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20Hz-45Hz	45Hz-10kHz	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	2 + 100	0.9 + 100	0.4V
3 mA	10 nA	2 + 100	0.6 + 100	0.4V
30 mA	100 nA	2 + 100	0.6 + 100	0.4V
300 mA	1 μA	2 + 100	0.6 + 100	0.5V
3 A	10 μA	2 + 100	0.6 + 100	2 V

[1] For sinewave inputs >2000 counts. For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for sinewave inputs >200Hz.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at ⅔ full scale.

NONSINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz, crest factor <3.

SETTLING TIME: 1 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V) accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C.

dB (Ref. = 1mA):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-10kHz	RESOLUTION
−34 to +69 dB (20μA to 3A)	0.2	0.01 dB
−54 to −34 dB (2μA to 20μA)	0.9	0.01 dB

MAXIMUM READING RATES[1]

DCV, DCA, ACV, ACA READINGS/SECOND

RESO-LUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	1000	1000	237	80	112	58
4½-Digit	333	333	145	63	91	49
5½-Digit	35 (29)	9 (7.5)	40 (33)	9 (7.5)	35 (29)	9 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

OHMS READINGS/SECOND

RESO-LUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	53	25	57	25	37	23
4½-Digit	43	20	47	21	30	19
5½-Digit	16 (13)	9.5 (7.5)	18 (15)	9.5 (7.5)	15 (12.5)	9.5 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

Offset Compensated Ohms: Rates are 0.5× normal mux on ohms rates.

[1] Reading rates are for on-range on-scale readings with internal filter off, for 3V, 3kΩ, and 3mA ranges. 6½- and 5½-digit rates are for 60Hz operation. Values in parentheses are for 50Hz operation.

[2] Internal filter on.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Reading Storage, Calibration, Display, Multiplex, Status, Service Request, Self Test, Output Format, TRANSLATOR.

Front Panel Programs

0	Menu
2	Display Resolution
4	mX + b
5	Hi/Lo/Pass
6	Multiplex On/Off
30	Save Setup
31	IEEE-488 Address
32	Line Frequency
33	Self Test
34	Set m, B Constants
35	Set Hi/Lo Limits
36	Digital Calibration
37	Reset to factory default conditions
Ω	Offset Compensation
ZERO	Zero Modify
FILTER	Filter Constants
dB	dB Reference

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 3029999 counts in 6½-digit mode.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

WARMUP: 2 hours to rated accuracy.

DISPLAY: 10, 0.5-in. alphanumeric LED digits with decimal point and polarity. Function and IEEE-488 bus status also indicated.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5×10^5 max. V·Hz product. $>10^9\Omega$ paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 readings/second (2/second on 30MΩ and 300MΩ ranges).

FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

OPERATING ENVIRONMENT: 0°-50°C, 0%-80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°C-50°C (0%-60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: −25° to +65°C.

POWER: 105-125V or 210-250V, rear panel switch selected, 50Hz or 60Hz, 30VA max. 90-110V and 180-220V versions available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.7kg (8 lbs.).

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

System DMM/193A

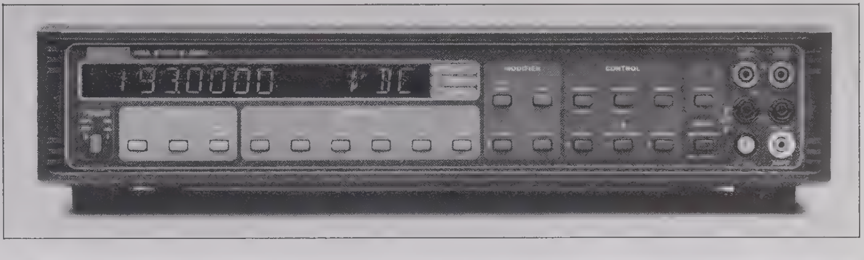
High Speed
Non-Volatile TRANSLATOR

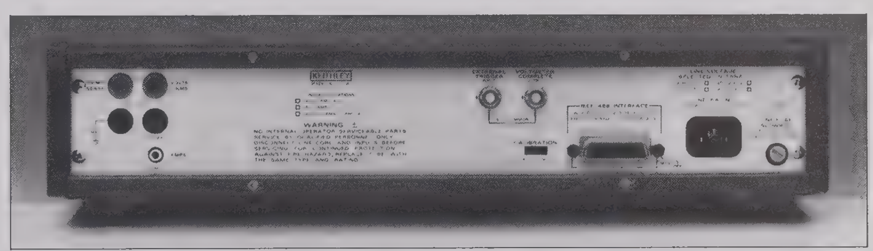
- **3½- to 6½-digit resolution**
- **Up to 1000 readings/second**

The Model 193A System DMM combines high speed, 9 functions, and superior performance into one of today's best values in instrumentation.

9 Measurement Functions:

Available Functions	Std.	Option 1930	Option 1931
1. DC Voltage	✓		
2. Resistance	✓		
3. dBV	✓		
4. AC Voltage		✓	
5. DC Current			✓
6. AC Current		✓	✓
7. Temperature (RTD)	✓		
8. Temperature (Thermocouple)	✓		
9. Low Freq. AC	✓		





Rear panel of Model 193A features rear inputs as well as EXTERNAL TRIGGER, VOLTMETER COMPLETE, and IEEE-488 connectors.

Speed. To maximize system throughput or monitor changes and trends, reading rates up to 1000/second are achievable.

Data Buffer. Up to 500 locations of non-volatile memory are available for data logging. Data can be recalled at any time without affecting the contents of the memory. HI, LO, and AVERAGE values are also available.

Trigger. The 193A can be triggered from the IEEE-488 bus, front panel, or through the EXTERNAL TRIGGER input on the rear panel. A separate trigger delay time can be programmed over the bus. VOLTMETER COMPLETE signals the system that the measurement data have been acquired.

Zero. The ZERO function subtracts any on-scale display reading from all subsequent measurements for relative readings or to compensate for unwanted background signals.

Filter. The FILTER control enables and disables a programmable weighted average digital filter to reduce noise encountered in the signal.

Digital Calibration. A recessed switch on the rear panel locks the calibration and can be covered for security.

Front/Rear Inputs. All inputs, including current, are available on front and rear panels. A front panel switch selects the appropriate inputs; its position is sensed and reported over the IEEE-488 bus.

Non-Volatile TRANSLATOR. A Keithley exclusive, the sophisticated TRANSLATOR software offers extraordinary programming flexibility. Define your own words to the 193A, and it will learn and respond. Advantages include:

- Using terminology with specific meaning to your application in place of cryptic mnemonics:
  Send `DCV` instead of `F0`.
- Abbreviate frequent setups to reduce IEEE-488 bus transfers:
  Send `TEST1` instead of
  `F3R1T2S0Z1U0M2P1X`.
- Translate Keithley commands to emulate functions of other units:
  Send `RA` to program AUTORANGE
  (as used by H-P) in place of `R0`.

Thus, the use of the TRANSLATOR can make programs more readable, reduce bus transfer times for instruction strings, and enable the 193A to upgrade a system without major changes to existing software. TRANSLATOR commands are retained in non-volatile memory.

ABBREVIATED TECHNICAL SPECIFICATIONS

DC VOLTS

(6½ Digits)

		ACCURACY[1] ±(%rdg + counts)		TEMPERATURE COEFFICIENT
RANGE	RESOLUTION	24 Hr.,[2] 23° ±1°C	90 Days, 18°-28°C	±(%rdg + counts)/°C 0°-18°C & 28°-50°C
200 mV	100 nV	0.0020 + 20[3]	0.005 + 20[3]	0.0006 + 10
2 V	1 μV	0.0013 + 10	0.003 + 20	0.0003 + 1
20 V	10 μV	0.0015 + 10	0.006 + 10	0.0007 + 1
200 V	100 μV	0.0025 + 10	0.006 + 10	0.0007 + 1
1000 V	1 mV	0.004 + 10	0.007 + 10	0.0007 + 1

[1] For 5½-digit accuracy, divide count error by 10.
[2] Relative to calibration standards.
[3] When properly zeroed.

CMRR: >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.
NMRR: >60dB at 50Hz or 60Hz (±0.05%).
MAXIMUM ALLOWABLE INPUT: 1000V peak.
INPUT RESISTANCE: >1GΩ except 10MΩ on 20V range and above.

193A/System DMM

High Speed
Non-Volatile TRANSLATOR

TRMS AC VOLTS (Option 1930)

(5½ Digits)

		ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C			
RANGE	RESOLUTION	20Hz-50Hz[2]	50Hz-10kHz[2]	10kHz-20kHz[2]	20kHz-100kHz[3]
2 V	10 μV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
20 V	100 μV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
200 V	1 mV	1 + 100	0.25 + 100	0.35 + 300	1 + 500
700 V	10 mV	1 + 100	0.35 + 100	0.5 + 300	1 + 500

[1] Multiply digit error by 10 for 6½-digit accuracy.

[2] For sinewave inputs >2,000 counts. [3] For sinewave inputs >20,000 counts.

RESPONSE: True root mean square, ac or ac+dc.

CREST FACTOR: Rated accuracy to 3. Specified for pulse widths >10μs, peak voltage ≤1.36 × range.

AC +DC: Add 60 counts to specified accuracy.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

3dB BANDWIDTH: 500kHz typical.

MAXIMUM ALLOWABLE INPUT: 1000V peak ac + dc, 2×10^7V•Hz.

SETTLING TIME: 0.5 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy spec.)/°C below 50kHz, ±(0.2x) for 50kHz-100kHz.

OHMS (6½ Digits)

			ACCURACY ±(%rdg + counts)		
RANGE	RESOLUTION	CURRENT THROUGH UNKNOWN	24 Hr., 23° ±1°C	1 Year, 18°-28°C	90 Days, 18°-28°C
200 Ω	100 μΩ	1 mA	0.0025 + 20	0.007 + 20	0.010 + 20
2 kΩ	1 mΩ	1 mA	0.0025 + 20	0.005 + 20	0.007 + 20
20 kΩ	10 mΩ	100 μA	0.0025 + 20	0.005 + 20	0.007 + 20
200 kΩ	100 mΩ	10 μA	0.0035 + 20	0.007 + 20	0.010 + 20
2 MΩ	1 Ω	1 μA	0.005 + 20	0.010 + 20	0.010 + 20
20 MΩ	10 Ω	100 nA	0.04 + 20	0.070 + 20	0.070 + 20
200 MΩ	1 kΩ	100 nA	3.2 + 2	3.2 + 2	3.2 + 2

CONFIGURATION: Automatic 2- or 4-wire.

MAX. ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

MAXIMUM OPEN CIRCUIT VOLTAGE: −7V.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 200Ω-20kΩ ranges, at 23°C ±1°C.

DC AMPS (Option 1931)

(5½ Digits)

RANGE	RESOLUTION	ACCURACY ±(%rdg +counts) 1 Year, 18°-28°C	MAXIMUM VOLTAGE BURDEN
200 μA	1 nA	0.09 + 10	0.25 V
2 mA	10 nA	0.09 + 10	0.25 V
20 mA	100 nA	0.09 + 10	0.25 V
200 mA	1 μA	0.09 + 10	0.28 V
2 A	10 μA	0.09 + 10	1 V

MAXIMUM ALLOWABLE INPUT: 2A, 250V.

OVERLOAD PROTECTION: 2A fuse (250V), accessible from front panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C), (±%rdg + counts)/°C: ±(0.001 + 0.5)/°C.

LOW FREQUENCY AC VOLTS (3½ Digits):

RANGES: 200mV to 700V.

ACCURACY (1 Year), ±(%rdg + counts): ±(2% rdg + 3 counts).

RESPONSE: True root mean square, ac + dc.

BANDWIDTH: 0.1 to 10Hz.

TRMS AC AMPS (Option 1930 and 1931)

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg+counts) 1 Year, 18°-28°C 45Hz-10kHz	MAXIMUM VOLTAGE BURDEN
200 μA	1 nA	0.6 + 300	0.25 V
2 mA	10 nA	0.6 + 300	0.25 V
20 mA	100 nA	0.6 + 300	0.25 V
200 mA	1 μA	0.6 + 300	0.28 V
2 A	10 μA	0.6 + 300	2 V

[1] For sinewave inputs >2000 counts.

RESPONSE: True root mean square, ac or ac + dc.

CREST FACTOR: Rated accuracy to 3. Specified for pulse width >1ms, peak current ≤1.36 × range.

AC + DC: Add 60 counts to specified accuracy.

SETTLING TIME: 0.5 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 2A, 250V.

OVERLOAD PROTECTION: 2A fuse (250V) accessible from front panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C), ±(%rdg + counts): 0.04 + 10.

ADDITIONAL FUNCTIONS

FUNCTION	REF.	RANGE	RESOLUTION
ACV dB	1 V	−34 to 57 dBV	0.01 dBV
ACA dB	1 mA	−54 to 66 dB	0.01 dB
Thermocouple Temperature*	Ext.	−100° to 1372°C	0.1°C (Types J, K, T, E)
RTD Temperature	DIN 43760 or IPTS-68	−100° to 630°C	0.01°C

*Over IEEE-488 bus only.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Rdg. Storage, Calibration, Display, MUX, Status, Service Request, Self Test, Output Format, Reference Junction, TRANSLATOR.

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 2199999 counts in 6½-digit mode, except 1000000 on 1000V dc range and 700000 on 700V ac range.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5×10^5 max. V·Hz product. $>10^9\Omega$ paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 rdgs/s (2/s on 20MΩ and 200MΩ ranges).

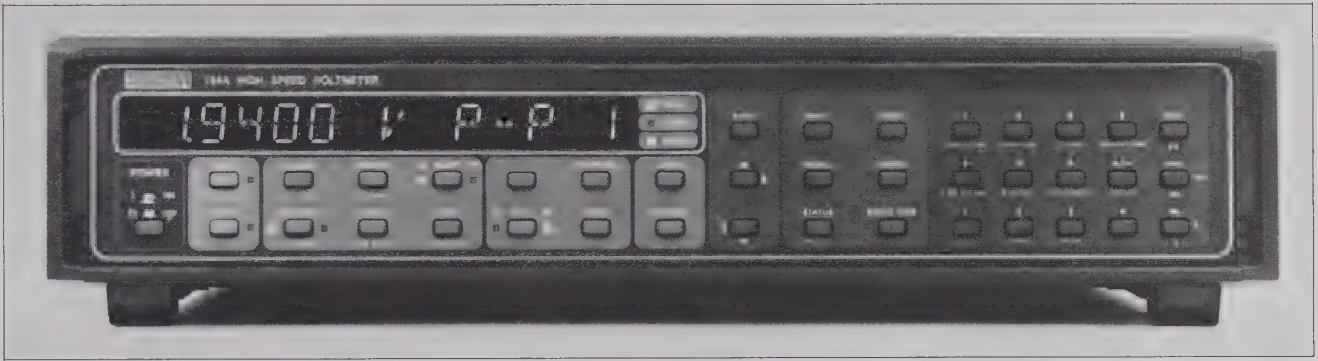
FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

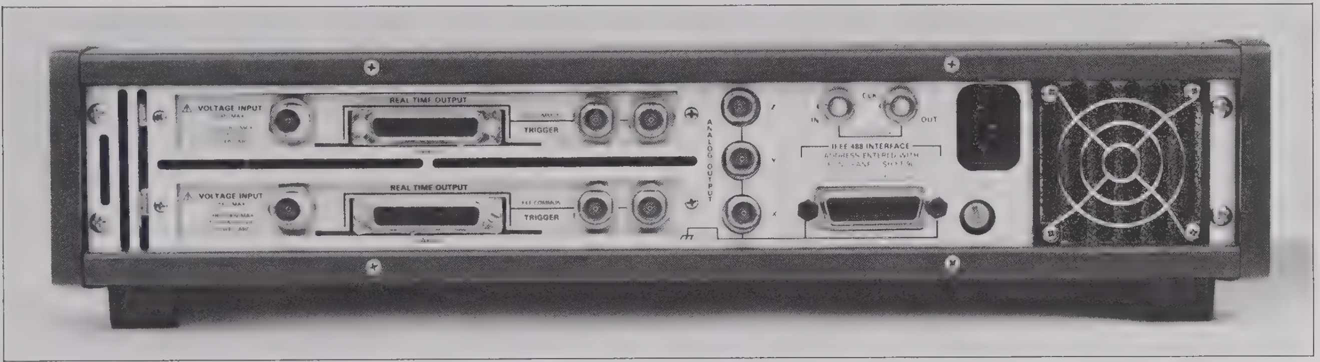
ENVIRONMENT: Operating: 0°-50°C, 0%-80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°-50°C (0%-60% RH up to 28°C on 200MΩ range). **Storage:** −25° to +65°C.

POWER: 105-125V or 210-250V, internal switch selected, 50Hz or 60Hz, 40VA max. 90-110V and 180-220V versions available upon request.

DIMENSIONS, WEIGHT: 89mm high × 438mm wide × 441mm deep (3½ in. × 17¼ in. × 17⅜ in.). Net weight 7.4kg (15 lbs.).

ACCESSORIES AVAILABLE: See Selector Guide on page 24.





Rear panel of Model 194A shows Model 1944A Channel 2 installed, as well as analog output, IEEE-488, and CLOCK IN/OUT *connectors.*

- **16-bit (4½-digit) resolution up to 100k samples/second**
- **64k bytes memory/channel**
- **Two independent, fully programmable channels**
- **External sample trigger rate to 1MHz**

The Model 194A high resolution digitizer can both acquire waveforms whose frequency components are below 500 kHz and take externally triggered samples at rates as high as 1M samples/second. With the Model 1944A Channel 2 option, two waveforms or two externally-triggered sets of samples can be taken simultaneously. In addition to waveform acquisition, the Model 194A also provides waveform analysis capability with eight built-in computation functions.

The 194A is a fully programmable IEEE-488 interfaceable instrument. The interface enables use in an automated system, where its full power can be realized.

High Resolution Digitizer. At sampling rates up to 100kHz, the 194A provides 16-bit (4½-digit) resolution. Thus the 194A is capable of detecting changes as small as 1 part in 32,000. This is far greater resolution than is provided by most other digitizing instruments, and enables the 194A to extract more information from a waveform. The 194A also accepts a wider range of input signals: it can detect as low as 10μV, and is designed to digitize up to 200V. Because its input is isolated, input signals need not be referenced to ground.

When greater speed is more important than high resolution, the 194A can sample at rates between 100kHz and 1MHz with 8-bit resolution. Unlike some digitizers, it is not limited to a fixed set of rate options: Any sampling time interval from 1.0μs to 1.0s can be programmed, and resolution is 0.1μs over the complete range of time intervals.

Extensive Memory. A total of 64k bytes of memory is available for sample storage. In 16-bit resolution mode, the 194A can store 32k samples; with 8-bit resolution, storage capacity increases to 64k samples. This is 16 times greater than the available memory in many other digitizing instruments.

The 194A can store data prior to a trigger event (pre-trigger) or delay the onset of data storage for a fixed time after a trigger event (post-trigger). Pre-triggering enables the investigation of phenomena that occurred prior to an event being studied; post-triggering avoids the collecting of an unwanted segment of information, such as a switching-related transient, following a trigger event.

Two Independent Channels. Two waveforms or two sets of samples can be acquired simultaneously or in time synchronization with the addition of the optional Model 1944A Channel 2. With the second channel installed, the Model becomes two entirely independent waveform acquisition channels, each with 64k of memory.

Measurement Triggers. For waveform acquisition, there is a choice of five trigger sources which are independently programmed for each channel: 1.) an input waveform at any level or slope; 2.) an external TTL control signal; 3.) an IEEE-488 command; 4.) the other channel; and 5.) manual, pushbutton trigger. Once triggered, the 194A digitizes at the programmed sampling rate.

External Sample Trigger. When high speed measurements synchronized to external events must be acquired, the Model 194A offers the fastest sample trigger rate available: 1MHz. For high throughput in component test systems or for data acquisition at varying sample intervals, the 194A can respond to external sample trigger pulses generated at intervals as short as 1μs. Examples of applications where fast external triggering is necessary include dynamic testing of A/D and D/A converter operation, in which sample acquisition must be synchronized to input source transitions, and measurements synchronized to non-constant mechanical rotations from a motor drive.

Waveform Analysis. The 194A directly computes and displays waveform parameters. It supplies a waveform's positive and negative peaks, the peak-peak, an average, or an RMS value. The RMS computation is accurate for any type of waveform. Unlike conventional DMMs, which convert an ac signal to a dc signal with a non-linear circuit, the 194A digitizes directly and mathematically computes the RMS. The RMS computation is not affected by non-linear circuit effects, and is not limited to signals of specific crest factors, as is a DMM.

The INTEGRATE function can be used to convert an acceleration waveform into a velocity. For statistical analysis, the standard deviation of a set of samples can be taken. With two channels, RATIO and DIFFERENCE functions can provide comparison information on two waveforms.

For test set-up and troubleshooting, or for hard copy output without a computer, analog outputs can transmit a stored waveform to an oscilloscope, a CRT monitor, a chart recorder, or an analog X-Y recorder.

High Speed IEEE-488 Bus Performance. The 194A is optimized to handle the large quantity of data that can be stored. In binary format, data can be transmitted over the IEEE-488 bus at 90k bytes/second. At this speed, the 194A can transfer the total contents of the 64k memory to a computer in under 1 second. Furthermore, each channel has a real time output port, so that data can be transferred as it is digitized. At the fastest sampling rate, samples can be output over the real time output port at 1M samples/second.

TRANSLATOR. Our exclusive TRANSLATOR software can reduce IEEE-488 bus traffic by converting long command strings into short, understandable mnemonics. For example, instead of having to transfer a long command string like:

```
F2R1S0/10E-6N1/250E-1I1P0X
```

you can send:

```
TEST1
```

Your code becomes more readable and, in this case, only 5 characters must be transferred over the bus as opposed to 26.

DC CHARACTERISTICS

	16 BIT		8 BIT	
RANGE	RESOLUTION	ACCURACY* ±(%rdg + offset) (1 Yr., 18°-28°C)	RESOLUTION	ACCURACY* ±(%rdg + offset) (1 Yr., 18°-28°C)
320 mV	10 μV	0.030% + 200 μV	2.56 mV	0.42% + 2.56 mV
3.2 V	100 μV	0.025% + 2 mV	25.6 mV	0.42% + 25.6 mV
32 V	1 mV	0.035% + 20 mV	256 mV	0.42% + 256 mV
200 V	10 mV	0.035% + 200 mV	2.56 V	0.42% + 2.56 V

*After pushbutton or bus zeroing, and using average function (10,000 samples, 10μs sample rate).

INPUT IMPEDANCE: 1.1MΩ (1.0MΩ on 200V range) shunted by <47pF.

MAXIMUM ALLOWABLE INPUT: 250V peak, 2×10^7V•Hz.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, 42V peak, 5×10^5 V•Hz.

COMMON MODE REJECTION RATIO: >60dB at dc to 1kHz, 1kΩ unbalance.

DIFFERENTIAL NONLINEARITY: 16-Bit: ≤2 LSB. 8 Bit: ≤0.5 LSB.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): < ±(0.1 × applicable accuracy specification)/°C.

DYNAMIC CHARACTERISTICS

SAMPLE TRIGGER: Initiates each A/D conversion.

EXTERNAL SAMPLE TRIGGER INPUT: Rising edge, TTL compatible. DB-25 connector.

	INTERNAL SAMPLE TRIGGER		EXTERNAL SAMPLE TRIGGER	
	16 BIT	8 BIT	16 BIT	8 BIT
SAMPLE RATE				
Maximum	100 kHz	1 MHz	100 kHz	1 MHz
SAMPLE INTERVAL				
Minimum	10 μs	1 μs	10μs	1 μs
Maximum	1 s	1 s	No limit	
Resolution	100 ns	100 ns	—	—
Jitter (typical)	±0.4 ns	±2 ns	±2 ns	±2 ns
TIMEBASE ACCURACY	±0.02%	±0.02%	±0.02%	±0.02%
NUMBER OF SAMPLES				
Minimum	1	1	1	1
Maximum	32k	64k	32k	64k

SIGNAL/NOISE RATIO (sinewave curve fit): 50dB for full range 100kHz sine input; 72dB typical at 10kHz.

SLEW RATE: 13V/μs minimum.

SETTLING TIME: 1 μs to 0.1% of final value.

CHANNEL CROSSTALK: <60dB at 500kHz.

INPUT COUPLING: Ac, dc, ground.

FREQUENCY RESPONSE (Filter Off):

0.2 dB	1 dB	3 dB
dc (15 Hz) - 20 kHz	dc (5 Hz) - 200 kHz	dc (2 Hz) - 750 kHz

( ) Indicates ac coupled performance.

LOW PASS FILTER: 50kHz, 500kHz, single pole.

MEASUREMENT TRIGGER

MEASUREMENT TRIGGER: Initiates acquisition of a set of samples.

DELAY:

Pre-Trigger: $-32k<n<-1$, 16-bit mode; $-64k<n<-1$, 8-bit mode. $|n|$ samples are stored prior to measurement trigger.

Post-Trigger: $1<n<1\times10^7$. Storage begins "n" samples after measurement trigger.

SOURCE:	Description
Input Signal	Slope: + or − Level: Selectable over input voltage range and resolution.
External:	Negative TTL edge, rear panel BNC.
Front Panel:	Manual pushbutton.
IEEE-488 Interface:	16 programmable trigger modes.
Other Channel:	Internally generated.

CHANNEL 2 (Option 1944A)

Permits synchronous or asynchronous sampling of data. Specifications are identical to those of Channel 1. All Channel 2 measurement parameters are independently selectable.

MATH FUNCTIONS

AVERAGE: $$\frac{\sum_{i=0}^{n-1} V_i}{n} = V_{avg}$$

PEAK TO PEAK: Difference between maximum and minimum values of samples.

PLUS PEAK: Maximum value of samples.

MINUS PEAK: Minimum value of samples.

STANDARD DEVIATION: $$\sqrt{\frac{\sum_{i=0}^{n-1} (V_i - V_{avg})^2}{n}}$$

TRUE ROOT MEAN SQUARE: $$\sqrt{\frac{\sum_{i=0}^{n-1} (V_i)^2}{n}}$$

INTEGRAL: $(\frac{1}{2}V_0 + \frac{1}{2}V_{n-1} + \sum_{i=1}^{n-2} V_i)\, t_s$.

DIFFERENCE: Channel 1 − Channel 2.

RATIO: Channel 1 / Channel 2.

NOTE: V_i: Voltage of sample i. **n:** Total number of samples. **i:** Location of individual sample. t_s: Sample interval.

REAL TIME (DMA) OUTPUT

FORMAT: Binary, 16-bit or 8-bit. **RATE:** Same as Sample Rate.

CONTROL LINES: End of Sample, Overrun, High Byte, Low Byte.

ANALOG OUTPUT

MODES	OUTPUTS USED
CRT	x, y, z (blanking)
Oscilloscope	y, z (trigger)
Slow Plot	x, y, z (pen up/down)
Strip Chart	y

X OUTPUT: 0-10V full scale, 2.44mV resolution.

Y OUTPUT: 0-10V full scale, 2.44mV resolution.

Z OUTPUT: 0V, 5V or 15V.

ZOOM MAGNIFICATION: 0.1:1 to 1000:1.

PAN: Across entire memory.

FRONT PANEL PROGRAMS

0 **IEEE ADDRESS:** Set IEEE-488 address.

1 **SELF TEST:** Performs internal RAM and ROM check.

2 **DIGITAL CALIBRATION:** Executes calibration procedure.

3 **CALIBRATION STORAGE:** Stores calibration constants in NVRAM.

4 **X OUTPUT FULL SCALE:** Sets full scale X output voltage.

5 **Y OUTPUT FULL SCALE:** Sets full scale Y output voltage.

6 **Z OUTPUT BLANKING LEVEL:** Sets high or low blanking level.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD, MLA, MTA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Math Functions, Zero, Delay, Sample Rate, Number of Samples, Trigger, Calibration, Output Format, Self Test, Display, Status, Service Request, Storage, Filter, Terminator, Input Coupling, Buffer Size, Channel, Save and Recall Setups, Front Panel Programs 1-6, Key Sequence, Slope, Analog Outputs, EOI.

BINARY TRANSFER RATE: 90k bytes/second.

GENERAL

DISPLAY: 14-digit alphanumeric LED display; function, bus status also displayed.

RANGING: Manual or autoranging.

WARMUP: One hour to rated accuracy.

OPERATING ENVIRONMENT: 0° to 50°C, 0% to 80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: −25° to 65°C.

POWER: 105-125V or 210-250V (internal switch selectable), 50Hz or 60Hz, 120VA maximum. 90-110V and 180-220V version available.

CONNECTORS: All I/O connectors are BNC except Real Time Output (DB-25) and IEEE-488 connectors.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in. × 17⅛ in. × 17⅝ in.). Net weight 9.1kg (20 lbs.), Dual Channel.

ACCESSORIES AVAILABLE: See Selector Guide on page 24.

Selector Guide/DMM Accessories

	169	179A	175	177	197	195A	196	193A	194A
FUNCTION OPTIONS									
Current	Std.	Std.	Std.	Std.	Std.	1950	Std.	1931	
TRMS AC		Std.	Std.	Std.	Std.	1950	Std.	1930	
Second Channel									1944A
OUTPUT OPTIONS									
Analog Output				Std.	1972[1]				Std.
BCD Output		1792		1792					
IEEE-488 Interface		1793	1753	1793	1973	Std.	Std.	Std.	Std.
PROBES/SHUNTS									
Temperature Probe	1301	1301	1301	1301	1301	1301, 869X[2]	1301		
High Voltage Probe	1600A	1600A	1600A	1600A	1600A	1600A	1600A	1600A	
RF Probe	1682A	1682A	1682A	1682A	1682A	1682A	1682A	1682A	
Current Probe	1685	1685	1685	1685	1685	1685	1685	1685	
50A Current Shunt	1651	1651	1651	1651	1651	1651	1651	1651	
TEST LEADS									
Kelvin					5806	5806	5806	5806	
Clip-On	1681	1681	1681	1681	1681	1681	1681	1681	
Universal	1683	1683	1754	1683	1754	1683	1754	1754	
General Purpose	1691[3]	1691[3]	1751[3]	1691	1751[3]	1691	1751[3]	1751	
CABLES, ADAPTERS									
BCD		1796		1796					
IEEE-488 (Shielded)		7007	7007	7007	7007	7007	7007	7007	7007
IEEE-488 (Standard)		7008	7008	7008	7008	7008	7008	7008	7008
BNC-BNC									7051
BNC-Alligator/Clip									7754
50Ω Terminator									7755
RTD Probe Adapter						1951[2]			
RTD Connector Kit						8691			
Sample Strobe Cable									1942
RACK MOUNT KITS									
Single Fixed	1010	1010	1010	1010	1010	1019A-1	1019A-1	1938	1938
Dual Fixed	1017	1017	1017	1017	1017	1019A-2	1019A-2		
Single Slide						1019S-1	1019S-1	1939	1939
Dual Slide						1019S-2	1019S-2		
POWER									
Line	1766	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Battery	Std.	1788	1758	1788	1978				
CARRYING CASES									
Soft Vinyl	1686	1686	1686	1686	1686				
Hard Shell	1684	1684	1684	1684	1684				
MISCELLANEOUS									
Spare Parts Kit	1699		1759	1779	1979				

See page 85 for descriptions of all accessories.

---

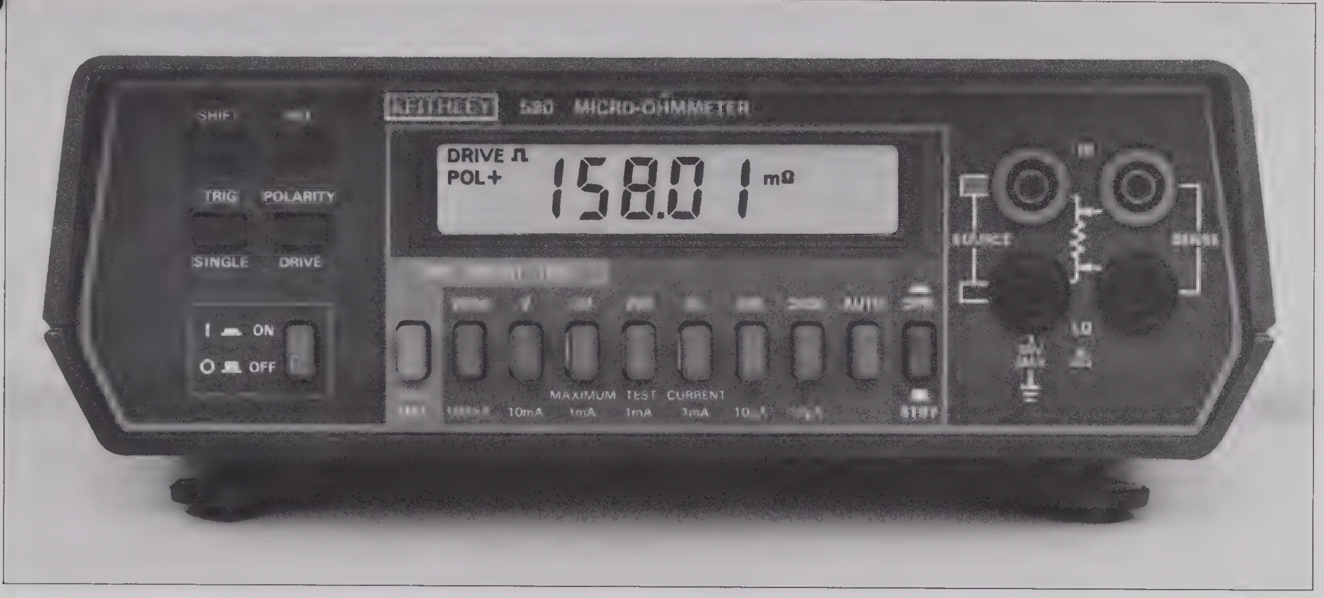
[1] Model 1972 IEEE-488 Interface with Analog Output.

[2] Platinum RTD Probes (Models 8693, 8695, 8696) may be used with Model 195A and optional Model 1951 RTD Probe Input Adapter.

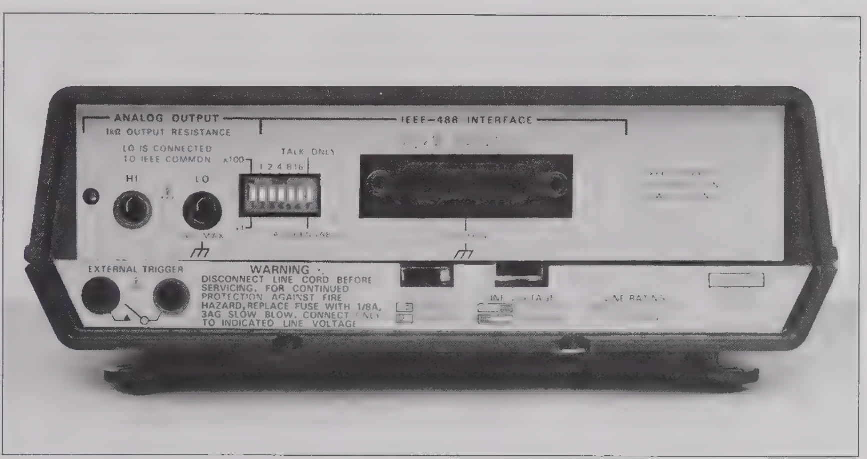
[3] Supplied accessory.

Micro-ohmmeter/580

10μΩ Sensitivity


KEITHLEY 580 MICRO-OHMMETER
DRIVE
POL+
158.01 mΩ
SHIFT
TRIG
POLARITY
SINGLE
DRIVE
ON
OFF
MAXIMUM TEST CURRENT
10mA
1mA
1mA
1mA
SOURCE
SENSE
HI
LO

- **20mV voltage clamp**
- **Selectable test current waveforms**
- **Optional IEEE-488 interface**
- **3 sets of test leads included**


ANALOG OUTPUT
1kΩ OUTPUT RESISTANCE
LO IS CONNECTED TO IEEE COMMON
HI
LO
TALK ONLY
IEEE-488 INTERFACE
EXTERNAL TRIGGER
WARNING
DISCONNECT LINE CORD BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH 1/8A, 3AG SLOW BLOW. CONNECT ONLY TO INDICATED LINE VOLTAGE

Rear panel of the Model 580 Micro-ohmmeter features external trigger connectors, calibration enable/disable switch, and line voltage selection switch.

The 580 Micro-ohmmeter combines high accuracy, resolution, and sensitivity with three special capabilities that make micro-ohm measurements easier and more versatile than ever:

1. When measuring contact and connector resistances, it is important to not puncture oxides and films that may have formed. The 580 ensures this dry circuit condition by clamping the open circuit test voltage to 20mV on the 200mΩ, 2Ω, and 20Ω ranges when the 20mV MAX button is pressed.

2. The 580 can test more devices by enabling both test current polarity and waveform (dc or pulsed) to be selected. When using pulsed test current, the 580 automatically compensates for thermal EMFs. Tests on inductive devices are best performed using dc test current, as this avoids the effects of time constants on pulsed current resistance measurements. For temperature-sensitive components, a single trigger mode of operation minimizes power delivered to the device. Single trigger operation is possible via either the front panel or an optional foot switch.

3. The optional IEEE-488 bus interface permits operation as a stand-alone unit as well as in a PC-based system

A microprocessor-based design gives the 580 a number of advanced capabilities. Resistance measurements can be made from 10μΩ to 200kΩ on seven ranges, with 4½-digit resolution and accuracy to within 0.04% of reading. Ranging can be performed either manually or automatically. Settling time is less than one second to within 10 counts on a given range.

The 580 is supplied with three sets of test leads—standard leads, Kelvin probes, and Kelvin clip leads—in a rugged strap-on pouch. For applications requiring portability or line power isolation, an optional battery pack is also available. Digital calibration is possible through front panel controls or over the optional IEEE-488 bus interface.

580/Micro-ohmmeter

10μΩ Sensitivity

			NON DRY CIRCUIT TEST		DRY CIRCUIT TEST	
			ACCURACY 1 Yr., 18°-28°C ±(%rdg+counts)			ACCURACY 1 Yr., 18°-28°C ±(%rdg+counts)
RANGE	RESOLUTION	MAXIMUM TEST CURRENT	PULSED	DC	MAXIMUM POWER DISSIPATION IN SAMPLE	PULSED
200 mΩ	10 μΩ	100 mA	0.04 + 2	0.04 + 3	500 μW	0.05 + 2
2 Ω	100 μΩ	10 mA	0.04 + 2	0.04 + 3	50 μW	0.05 + 2
20 Ω	1 mΩ	1 mA	0.04 + 2	0.04 + 3	5 μW	0.05 + 2
200 Ω	10 mΩ	1 mA	0.04 + 2	0.04 + 2		
2 kΩ	100 mΩ	1 mA	0.04 + 2	0.04 + 2		
20 kΩ	1 Ω	10 μA	0.05 + 2	0.05 + 2		
200 kΩ	10 Ω	10 μA	0.075 + 2	0.075 + 2		

CONFIGURATION: 4-wire (two sense, two source).

MAXIMUM SOURCE VOLTAGE: 20mV in Dry Circuit Test, 1V otherwise.

MAXIMUM TEST LEAD RESISTANCE

200mΩ and 2Ω Ranges: Up to 5Ω in each SOURCE lead and 10Ω in each SENSE lead with Non Dry Circuit Test; up to the selected full range resistance in each SOURCE lead and 10Ω in each SENSE lead with Dry Circuit Test.

20Ω through 200kΩ Ranges: Up to half of the selected range in each test lead.

CONVERSION RATE: 3 readings/second typical.

RANGING: Auto or manual.

AUTORANGING TIME: 200 ms per range change, average.

SETTLING TIME: <1 second to within 10 counts on range.

MAXIMUM INPUT OVERLOAD: 10V limited to 10A.

MAXIMUM COMMON MODE VOLTAGE: 30V rms at dc, 50 or 60Hz.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.1 × applicable accuracy specification)/°C.

ISOLATED ANALOG OUTPUT/IEEE-488 INTERFACE (Model 5802 Option)

ANALOG OUTPUT

LEVEL: 1V = 10,000 counts on ×1 gain.
1V = 100 counts on ×100 gain.
Maximum output voltage = ±4V.

ACCURACY: ±(0.25% of displayed reading+2mV). In ×100, 2mV output = 0.2 displayed counts.

RESPONSE TIME: Follows display conversion rate.

OUTPUT RESISTANCE: 1000Ω.

ISOLATION: ANALOG OUTPUT LO is connected to IEEE COMMON. Maximum common mode voltage from IEEE COMMON to earth ground is 30V rms at dc, 50 or 60Hz.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD, LLO.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, DRY CIRCUIT TEST, Operate, RELative, POLARITY, DRIVE, TRIGger, Calibration, EOI, SRQ, Status, Data Format, Terminator.

GENERAL

DISPLAY: ±20,000 count LCD, range and status information displayed.

OVERRANGE INDICATION: "OL" displayed.

CONNECTORS: Measurement and rear panel EXTERNAL TRIGGER inputs: Banana jacks.

RELative: Allows zeroing of on-range readings. Allows readings to be made with respect to baseline value. Display annunciator indicates REL.

DRIVE: Selects either pulsed or dc SOURCE current. Pulsed drive provides automatic cancellation of thermal offsets, using 50% duty cycle pulse. Display annunciator indicates drive selected.

POLARITY: Selects either positive or negative SOURCE current in either drive. Display annunciator indicates polarity selected.

TRIGger: Allows single pulsed measurements.

OPERATING ENVIRONMENT: 0°-50°C, <80% relative humidity up to 35°C; linearly derate 3% R.H./°C from 35° to 50°C.

STORAGE ENVIRONMENT: −25° to 60°C.

POWER: 105-125V or 210-250V (switch selected), 90-110V available. 50-60Hz, 12VA. Optional 6-hour battery pack, Model 1978.

DIMENSIONS, WEIGHT: 89mm high × 241mm wide × 300mm deep (3½ in. × 9½ in. × 11¾ in.). Net weight 3.2kg (7 lbs.). Test lead pouch adds 76mm (3 in.) in height.

ACCESSORIES SUPPLIED: Models 5801, 5804, 5805, 5806, Operator's and Service Manuals.

ACCESSORIES AVAILABLE:

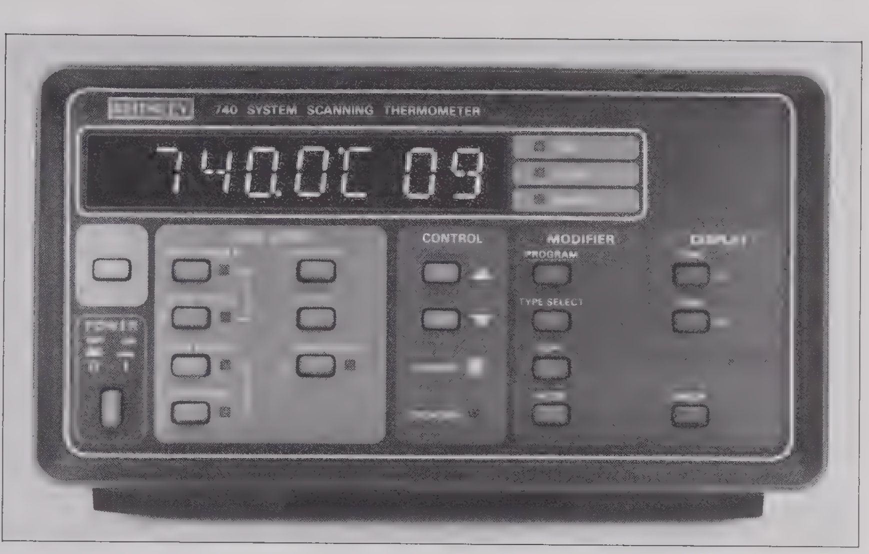
Model 1010:	Single Rack Mounting Kit
Model 1017:	Dual Rack Mounting Kit
Model 1755:	Calibration Interface
Model 1978:	Rechargeable Battery Pack
Model 5801:	Test Lead Pouch
Model 5802:	Isolated Analog Output/IEEE-488 Interface
Model 5804:	Test Lead Set
Model 5805:	Kelvin Probes
Model 5806:	Kelvin Clip Leads
Model 7007-1:	Shielded IEEE-488 Digital Cable (1m)
Model 7007-2:	Shielded IEEE-488 Digital Cable (2m)
Model 7008-3:	IEEE-488 Digital Cable, 0.9m (3 ft.)
Model 7008-6:	IEEE-488 Digital Cable, 1.8m (6 ft.)
Model 8003:	Low Resistance Test Fixture

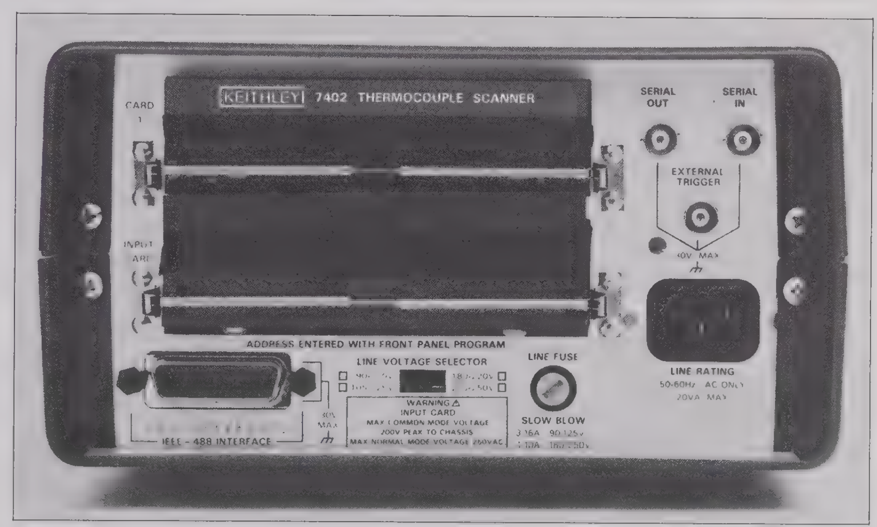
See page 85 for descriptions of all accessories.

Programmable Thermometer/740

System/Bench

- **Multiplex 9 thermocouple inputs**
- **Expand to 81 inputs**
- **Thermocouples types J, K, T, E, R, S, or B**
- **°C, °F, or mV readings**
- **Store temperature profiles**
- **Record temperature trends**


KEITHLEY
740 SYSTEM SCANNING THERMOMETER
740.0C 09
CONTROL
MODIFIER
PROGRAM
TYPE SELECT
DISPLAY


KEITHLEY 7402 THERMOCOUPLE SCANNER
CARD 1
SERIAL OUT
SERIAL IN
EXTERNAL TRIGGER
40V MAX
ADDRESS ENTERED WITH FRONT PANEL PROGRAM
LINE VOLTAGE SELECTOR
LINE FUSE
SLOW BLOW
WARNING
INPUT CARD
MAX COMMON MODE VOLTAGE
200V PEAK TO CHASSIS
MAX NORMAL MODE VOLTAGE 250VAC
IEEE - 488 INTERFACE
LINE RATING
50-60Hz AC ONLY
20VA MAX

Rear panel of Model 740 mainframe shows optional Model 7402 Thermocouple Scanner Card installed.

The Model 740 Programmable Thermometer has a built-in reference junction and will linearize any of 7 different thermocouple types. The Model 740/7402 combination includes nine channels of thermocouple input. An IEEE-488 interface port is included for easy system integration or connection to an IEEE-488 printer for datalogging.

Input Expansion. The Model 740/7402 can be expanded up to 81 inputs by selecting a Model 705 or 706 Scanner and configuring these with additional 7402 or 7057A thermocouple scanner cards, each with 9 inputs. The control for these expansion units is through a serial loop connected by standard coaxial cable, thereby allowing expansion without using additional IEEE-488 addresses.

Input Programming. Each input can be selected for any of J, K, T, E, R, S, or B type thermocouples, or for voltage readback up to 100mV with 1μV sensitivity. Any input can also be turned off, allowing the instrument to skip that channel in the scan sequences. Open thermocouple conditions are detected and displayed.

Monitor Temperature Trends. A single input can be read at programmable intervals to monitor temperature trends. Rates up to 20 readings/second are available for determining rapid temperature variations, and the data can be stored in the internal memory. Data can also be transferred to a computer file over the built-in IEEE-488 bus.

Locate hot spots and examine time-dependent thermal characteristics. Scan intervals are programmable, and the maximum rate of 20 readings/second assures a minimum of time skew between input samples for monitoring temperature changes.

A SMART PRINT feature can locate the address and send data to any IEEE-488 printer for data logging of results in a bench configuration.

Non-Volatile Memory. An internal memory stores up to 100 readings. Data can be recalled from the front panel or transferred in a block transfer to a controller. The Model 740 will also give HI, LO, and AVERAGE of the data memory.

Simple, Reliable Calibration. Calibration of the Model 740 is easy—there are no mechanical adjustments. Simply present the the calibration voltages to the input and tell the instrument to calibrate. Constants are stored in non-volatile memory to maintain the instrument's accuracy.

740/Programmable Thermometer

System/Bench

ACCURACY*

TYPE	RANGE	1 Year 18°-28°C (65°-82°F)
mV	−99.999 to 100.000 mV	±(0.02% + 3 μV)
J	−100.0°C to + 760.0°C −148.0°F to +1400.0°F	±0.4°C ±0.8°F
K	−100.0°C to +1372.0°C −148.0°F to +2501.0°F	±0.5°C ±0.9°F
T	−100.0°C to + 400.0°C −148.0°F to + 752.0°F	±0.5°C ±0.8°F
E	−100.0°C to +1000.0°C −148.0°F to +1832.0°F	±0.5°C ±0.9°F
R	0 °C to +1780 °C + 32 °F to +3236 °F	±1 °C ±2 °F
S	0 °C to +1780 °C + 32 °F to +3236 °F	±1 °C ±2 °F
B	+350 °C to +1820 °C +662 °F to +3308 °F	±1 °C ±2 °F
EXTENDED RANGE (Types J, K, T, E):		
	−200.0°C to − 100.1°C −328.0°F to − 148.0°F	±0.6°C ±1.0°F

mV INPUT RESISTANCE: >1 GΩ.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <(0.1 × rated accuracy)/°C.

INPUT CURRENT: 800pA maximum during measurement; 60μA maximum during open thermocouple check.

COMMON MODE REJECTION RATIO (at dc, 50 and 60Hz, 100Ω unbalance):** <0.0003°C/V with filter enabled (160dB); <0.003°C/V with filter disabled (140dB).

NORMAL MODE REJECTION RATIO (at 50 and 60Hz):** <0.003°C/mV with filter enabled (80dB); <0.03°C/mV with filter disabled (60dB).

*Excludes thermocouple errors (specifications include Model 7057A errors).

**Based on >30μV/°C slope.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD, MLA, MTA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, E1, C28.

PROGRAMMABLE PARAMETERS: EOI, Terminator, SRQ, Status, Trigger, Self Test, Calibration, Filter, Function, Scan Interval, Log Interval, Time & Date, Time of Day Trigger, Date Format, Alarm Limits, Output Format, Channel Number, Data Buffer, Scale, Display, Channel Type.

GENERAL

MAXIMUM ALLOWABLE INPUT: 250V rms, 350V peak (for one minute).

MAXIMUM COMMON MODE VOLTAGE: 200V peak to earth.

MAXIMUM THERMOCOUPLE LOOP RESISTANCE: 1kΩ.

FILTER SETTLING TIME: 100ms (typical).

SCANNING RATE: >20 channels/second, filter disabled; >5 channels/second, filter enabled.

BENCH READING RATE: 8 readings/second, filter disabled; 4 readings/second, filter enabled.

LOGGING INTERVAL: One of 12 selectable rates from 50ms to 1 hour, or triggered.

SCANNING INTERVAL: One of 10 selectable rates from 500ms to 1 hour, or triggered.

DISPLAY: Eight 0.5-inch alphanumeric LED digits with decimal point and polarity. Function, Filter, Channel, Location, Overflow, Open Thermocouple, and IEEE bus status also displayed.

INTERNAL CLOCK: Displays hour/minute/second; <1 minute/month error (typical).

WARMUP: 1 hour to rated accuracy.

CONNECTORS: 3 BNC: External Trigger, Serial-In, Serial-Out (TTL compatible). Quick disconnect connectors on input card.

CHANNEL CONFIGURATION: Types J, K, T, E, R, S, B, mV, or Off for each channel.

DATA MEMORY: Battery backed up one week minimum.
Single Channel Log: 100 locations (reading, location, time taken).
Multi-Channel Scan: 90 locations (reading, channel number, time taken).
Configuration: 81 locations (channel type selected).

CAPACITY: Single channel or 10 channels (including reference junction) using one 7402 or 7057A thermocouple scanner card. Up to 90 channels (including reference junctions) using 8 additional thermocouple scanner cards and one Model 706 or four Model 705 scanners.

OPERATING ENVIRONMENT: 0°-50°C; <80% relative humidity up to 35°C; linearly derate 3%RH/°C, 35°-50°C.

STORAGE ENVIRONMENT: −25° to +60°C

POWER: 105-125V or 210-250V (external switch selected), 20VA, 90-110V available; 50-60Hz.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.0kg (9 lbs.).

MAINFRAME CONFIGURATIONS:
740: System Scanning Thermometer
740/7402: 9-Channel Scanning Thermometer

SCANNERS:
Model 705: 20-Channel Scanner Mainframe
Model 706: 100-Channel System Scanner

ACCESSORIES AVAILABLE:

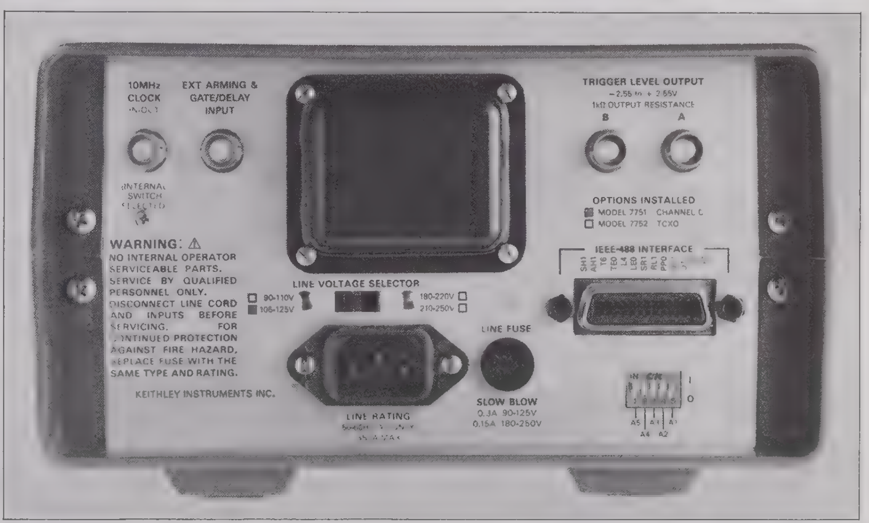
Model 1019A-1:	Single Fixed Rack Mount Kit
Model 1019A-2:	Dual Fixed Rack Mounting Kit
Model 1019S-1:	Single Slide Rack Mount Kit
Model 1019S-2:	Dual Slide Rack Mounting Kit
Model 7007-1:	Shielded IEEE-488 Cable, 1m (3.2 ft.)
Model 7007-2:	Shielded IEEE-488 Cable, 2m (6.5 ft.)
Model 7008-3:	IEEE-488 Digital Cable, 0.9m (3 ft.)
Model 7008-6:	IEEE-488 Digital Cable, 1.8m (6 ft.)
Model 7051-2:	BNC Interconnect Cable, 2 ft.
Model 7051-5:	BNC Interconnect Cable, 5 ft.
Model 7057A:	Thermocouple Scanner Card
Model 7401:	Thermocouple Wire Kit; contains 100 feet of type K thermocouple wire
Model 7402:	Thermocouple Scanner Card

See page 85 for descriptions of all accessories.

Programmable Counter-Timer/775A

- **9 digits/second resolution**
- **Dual input**
- **Optional Channel C and TCXO**
- **IEEE-488 programmable**

KEITHLEY 775A PROGRAMMABLE COUNTER/TIMER
123456789 3
CHAN A
DC/AC
ATTEN
FLTR
SLOPE
LEVEL
POWER


10MHz CLOCK
EXT ARMING & GATE/DELAY INPUT
INTERNAL SWITCH SELECTED
WARNING:
NO INTERNAL OPERATOR SERVICEABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD AND INPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING.
KEITHLEY INSTRUMENTS INC.
LINE VOLTAGE SELECTOR
90-110V
105-125V
180-220V
210-250V
LINE RATING
LINE FUSE
SLOW BLOW
0.3A 90-125V
0.15A 180-250V
TRIGGER LEVEL OUTPUT
−2.55 to +2.55V
1kΩ OUTPUT RESISTANCE
B
A
OPTIONS INSTALLED
MODEL 7751 CHANNEL C
MODEL 7752 TCXO
IEEE-488 INTERFACE
A5
A4
A3
A2
A1

Rear panel of Model 775A features connectors for time base in/out, external arming and gate/delay, trigger level output, and IEEE-488.

Keithley's Model 775A Programmable Counter/Timer brings you nine digits of resolution per second and six functions. The 775A uses two identical channels (A and B), each measuring frequency from dc to 120MHz. In addition, you can measure period, period average, time interval A to B, totalize, and pulse width using Channel A. For low frequency and slow transition events, a selectable 100kHz low pass filter prevents the instrument from triggering on noise.

Reciprocal Counting. The 775A uses a reciprocal counting technique to yield 9 digits of resolution, even when measuring low frequency signals. Nine digit per second resolution is achieved by multiplying the 10MHz clock frequency to an effective frequency of 100MHz. This microprocessor-based technique is usually found only in more expensive instruments.

Choice of Time Bases. Keithley offers a standard 10MHz time base with better than 0.5ppm/month stability. A TCXO (temperature compensated crystal oscillator) is included with the Channel C option; or, an external reference can be input.

Triggers. Flexible triggering with programmable control over levels, slope, coupling, and delay assure repeatable measurements on difficult waveforms. Trigger levels are variable in 10mV steps from −2.50 to +2.50 volts. A fast search mode rapidly sequences through the range of trigger levels until a valid trigger is detected; this can also be used to determine positive and negative waveform peaks. Programmable trigger delay can hold off the measurement for circuit settling.

Options. The 775A is available with a Channel C input for frequency measurements from 50MHz to 1.3GHz. This option also includes a TCXO with 0.1 ppm/month stability.

System Compatibility. IEEE-488 interface is included in the base price. System features such as external arming and gate/delay input assure flexibility. And all bench controls are programmable.

The 775A is both easy to use and easy to integrate into your system. Simple mnemonic command simplify programming, and consistent bus implementation with other Keithley programmable instruments assures predictable bus operation.

775A/Programmable Counter-Timer

System/Bench

INPUT CHARACTERISTICS (Ch. A & B, each channel)

RANGE: 0 to 120MHz, dc coupled; 30Hz to 120MHz, ac coupled.

SENSITIVITY (×1): 25mV rms, <10MHz; 50mV rms, >10MHz.

DYNAMIC RANGE (×1): 50mV to 5V p-p, <20MHz; 140mV to 2.5V p-p, >20MHz.

COUPLING: ac or dc, switchable.

IMPEDANCE: 1MΩ nominal, shunted by <60pF.

ATTENUATOR: ×1 or ×10 nominal, switchable.

LOW PASS FILTER: −10dB at 100kHz nominal, switchable.

SIGNAL OPERATING RANGE (×1): −2.55V dc to +2.55V dc.

TRIGGER LEVEL: −2.55 to +2.55V dc, ×1; −25.5 to +25.5V dc, ×10.

TRIGGER LEVEL RESOLUTION: 10mV, ×1; 100mV, ×10.

TRIGGER LEVEL SETTING ACCURACY: ±(35mV + 2% setting), ×1; ±(350mV + 2% setting), ×10.

TRIGGER LEVEL SETTING OUTPUT: Via rear panel BNC, not adjusted for attenuators.

SLOPE: + or − slope, switchable.

DAMAGE LEVEL:	×1:	dc—2kHz	250V dc + peak ac
		2kHz—100kHz	5 × 10^5V rms · Hz/frequency
		>100kHz	5V rms
	×10:	dc—20kHz	250V dc + peak ac
		20kHz—100kHz	5 × 10^5V rms · Hz/frequency
		>100kHz	50V rms

FREQUENCY A, B

RANGE: 0.1Hz to 120MHz.

LSD DISPLAYED: (10ns × frequency)/gate time.

RESOLUTION:
±1 LSD ± [(1.4 × trigger error + 2ns) × frequency]/gate time.

ACCURACY: ±Resolution ± (time base error × frequency).

DIGITS DISPLAYED: 8 per second of gate time, minimum.

PERIOD A

RANGE: 10ns to 10^4 seconds. **LSD DISPLAYED:** 10ns to 0.1ms.

ACCURACY: ±1 LSD ± (time base error × period) ± trigger error.

PERIOD AVERAGE A

RANGE: 10ns to 10 seconds.

LSD DISPLAYED: (10ns × period)/gate time.

RESOLUTION:
±1 LSD ± [(1.4 × trigger error + 2ns) × frequency]/gate time.

ACCURACY: ±Resolution ± (time base error × period).

NUMBER OF PERIODS AVERAGED: Gate time/period.

GATE/DELAY

INTERNAL GATE TIME: Variable from 100µs to 10 seconds in 45 increments, or one period of the input, whichever is longer. May be used in frequency and period average measurements.

EXTERNAL GATE TIME: Continuously variable from 100µs to 10 seconds, or one period of the input, whichever is longer.

EXTERNAL GATE DELAY: 10µs + one period of the input signal, maximum.

INTERNAL DELAY TIME: Variable from 100µs to 10s in 45 increments. May be used in period, time interval, and pulse width measurements.

EXTERNAL DELAY TIME: Continuously variable from 100µs to >1 hour.

EXT. GATE/DELAY INPUT: Positive TTL signal via rear panel BNC.

TIME INTERVAL A→B

RANGE: 10ns to 10^4 seconds. **LSD DISPLAYED:** 10ns to 0.1ms.

ACCURACY: ±1 LSD ± (time base error × time interval) ± trigger error ± trigger timimg error ± 2ns.

PULSE WIDTH A (Positive or Negative)

RANGE: 10ns to 10^4 seconds. **LSD DISPLAYED:** 10ns to 0.1ms.

ACCURACY: ±1 LSD ± (time base error × pulse width) ± trigger error ± trigger timimg error ± 2ns.

TOTALIZE

MODES: A gated by B; cumulative. **RANGE:** 0 to $10^{16}-1$.

REPETITION RATE: 120MHz maximum. **ACCURACY:** ±LSD.

LSD DISPLAYED: 1 count up to $10^{10}-1$; beyond $10^{10}-1$ use (1 part in 10^9 × displayed exponent).

TIME BASE

FREQUENCY: 10MHz. **AGING RATE:** ≤5×10^{-7}/month.

TEMPERATURE: ±5×10^{-6}, 0° to 40°C, ref. 25°C.

TIME BASE OUT: 2V minimum @ 10MHz, 100Ω output resistance.

OPTION CONFIGURATION (Model 775A/51/52 only)

Channel C: Frequency

RANGE: 50MHz to 1.3GHz. **COUPLING:** ac. **IMPEDANCE:** 50Ω.

SENSITIVITY: 15mV, 50MHz to 1.0GHz; 25mV, 1.0GHz to 1.2GHz; 75mV, 1.2GHz to 1.3GHz.

DYNAMIC RANGE: 25mV rms to 1V rms.

DAMAGE LEVEL: dc - 100kHz: 15V dc + peak ac; >100kHz: 5V rms.

TCXO

FREQUENCY: 10MHz. **AGING RATE:** <1×10^{-7}/month.

TEMPERATURE: ±1×10^{-6}, 0° to 40°C, ref. 25°C.

LINE VOLTAGE: <1×10^{-7} for 10% change.

TIME BASE OUT: 2V min. @ 10MHz, 100Ω output resistance, via rear panel BNC.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All front panel controls (except Power) plus Reading Rate, Data Format, Trigger, EOI, Terminator, Service Request, Self Test, Display, Status.

READING RATES: One shot, normal (3/s), fast (25/s), or dump (140/s).

GENERAL

DISPLAY: Nine LED digits with decimal point and exponent.

BENCH READING RATES: One shot or normal (3/second).

ARMING (TRIGGER): Each channel is armed by its own signal; or RESET button or EXT ARMING input when in one shot (HOLD) mode.

ARMING DELAY: 30µs in Frequency and Period Average; 10µs in Period, Time Interval, and Pulse Width.

EXT. ARMING INPUT: Positive edge TTL signal via rear panel BNC.

EXTERNAL TIME BASE INPUT: 10MHz TTL signal via rear panel BNC.

GATE: LED indicator lights when gate is open.

WARMUP: 2 hours to rated accuracy.

OPERATING TEMPERATURE: 0° to 40°C, 0% to 80% relative humidity.

STORAGE TEMPERATURE: −25° to 65°C.

POWER: 105-125V or 210-250V (rear panel switch selected), 50-60Hz, 35VA max. 90-110V available.

DIMENSIONS, WEIGHT: 127mm high × 215mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.5kg (8 lbs.).

ACCESSORIES AVAILABLE:

Model 1019A-1:	5¼-in. Single Fixed Rack Mounting Kit
Model 1019A-2:	5¼-in. Dual Fixed Rack Mounting Kit
Model 1019S-1:	5¼-in. Single Slide Rack Mounting Kit
Model 1019S-2:	5¼-in. Dual Slide Rack Mounting Kit
Model 7007-1:	Shielded IEEE-488 Cable, 1m (3.2 ft.)
Model 7007-2:	Shielded IEEE-488 Cable, 2m (6.5 ft.)
Model 7008-3:	IEEE-488 Digital Cable, 0.9m (3 ft.)
Model 7008-6:	IEEE-488 Digital Cable, 1.8m (6 ft.)
Model 7051-2:	BNC Interconnect Cable, 2 ft.
Model 7051-5:	BNC Interconnect Cable, 5 ft.
Model 7754-3:	BNC to Alligator Cable, 3 ft.
Model 7755:	50Ω Feedthrough Terminator

See page 85 for descriptions of all accessories.

MODEL	FEATURES	INPUT CONNECTION	CURRENT		VOLTAGE		RESISTANCE		CHARGE	
			FROM	TO	FROM	TO	FROM	TO	FROM	TO
602	Battery power. Analog. Floating input.	Triax	1fA	300mA	10μV	10V	10Ω	10TΩ	1fC	1μC
610C	Low cost. Analog.	UHF	1fA	300mA	10μV	100V	1Ω	100TΩ	1fC	10μC
614	4½ digits. Low cost. Current suppression. Battery powered.	Triax	10fA	2mA	10μV	20V	1Ω	200GΩ	10fC	20nC
617	4½ digits. Autoranging. IEEE programmable. Built-in 100V source.	Triax	400aA	20mA	10μV	200V	100mΩ	10PΩ	10fC	20nC
619	Dual channel*. Systems. 40 readings/second.	Triax	100fA	2A	10μV	200V	100mΩ	2TΩ	External Capacitor	
642	4½ digits. High sensitivity. BCD, IEEE output options.	BNC, special sapphire adapter	40aA	100nA	20μV	11V	N/A		800aC	100pC
427	High speed amplifier.	BNC	3fA	1mA						
485	4½ digits. Autoranging. IEEE programmable*.	BNC	100fA	2mA						
480	4½ digits. LED display.	BNC	1pA	2mA						
18000-20	High speed. Programmable.	Microdot	600fA	1mA						
26000 Series	Logarithmic.	BNC	10fA	1mA						

*Optional

Standard Symbols

PREFIXES		
SYMBOL	PREFIX	EXPONENT
a	atto-	10^{-18}
f	femto-	10^{-15}
p	pico-	10^{-12}
n	nano-	10^{-9}
μ	micro-	10^{-6}
m	milli-	10^{-3}
(none)	(none)	10^{0}
k	kilo-	10^{3}
M	mega-	10^{6}
G	giga-	10^{9}
T	tera-	10^{12}
P	peta-	10^{15}
E	exa-	10^{18}

QUANTITIES		
SYMBOL	UNIT	QUANTITY
V	volts	EMF
A	amperes	current
Ω	ohms	resistance
C	coulombs	charge
s	seconds	time
W	watts	power
F	farads	capacitance

The goal of any electrical current measurement is to insert an ammeter in the circuit in a way that allows the current indicated on the ammeter to be equal to the current originally flowing through the circuit under test (see **Figure 1a**). This measurement is to be carried out to within some acceptable uncertainty. Any ammeter can be modeled to consist of three separate circuit elements shown in **Figure 1b**: a shunt resistance R_{SH} that arises from the cable connected to the meter; a generator of unwanted electrical current I_E, which represents mainly currents generated by the cabling and connectors; and an internal meter resistance R_M, which includes series cable resistance. The internal resistance is in series with an ideal ammeter M_I having no resistance or current source of its own.

When the ammeter is connected in the circuit, the current indicated on the meter is equal to the current that would flow through the circuit if the ammeter were not inserted, plus or minus errors due to elements in the circuit model. These errors consist of current I_{SH} flowing through shunt resistance R_{SH}, currents generated in the interconnection I_E, inherent meter uncertainty U_M, and errors induced by voltage burden (or drop) V_M across the ammeter.

SHUNT vs. FEEDBACK AMMETERS

There are two techniques for making low-current measurements: the shunt ammeter and the feedback ammeter technique. Picoammeters and the AMPS function of newer electrometers use the feedback ammeter configuration only. The major difference between picoammeters and electrometers is that electrometers are multifunction instruments while picoammeters measure only current.

Shunt Ammeter

Shunting the input of a voltmeter with a resistor forms a shunt ammeter (**Figure 2**). For any given I_{IN}, several combinations of R_S and voltage sensitivity are possible.

$$E_2 = I_{IN}R_S$$

$$E_O = E_2\left[\frac{R_A+R_B}{R_B}\right] = I_{IN}R_S\left[\frac{R_A+R_B}{R_B}\right]$$

This circuit is typically used in sensitive DMMs, which have a voltage burden of 200mV or more.

Feedback Ammeter

In this configuration, shown in **Figure 3**, the input current (I) flows through the feedback resistor R_F. The low offset current of amplifier A changes the current I by a negligible amount. Circuit analysis shows:

$$E_O + IR_F = E_1$$

$$E_O = -AE_1\text{, and } E_1 = -\frac{E_O}{A}.$$

$$\text{Thus, } E_O+IR_F = -\frac{E_O}{A}$$

$$\text{and } E_O\left[1+\frac{1}{A}\right] = -IR_F.$$

$$\text{Since } A \gg 1\text{, } E_O = -IR_F$$

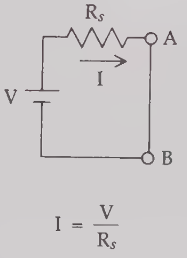
$$\text{and } |E_1| = \frac{E_O}{A} \ll E_O.$$

Thus the output voltage is a measure of input current. Sensitivity is determined by the feedback resistor R_F. The low voltage burden E_1 and corresponding fast rise time are achieved by the high gain op amp which forces E_1 to be nearly zero. Typical voltage burdens of picoammeters and electrometers using this circuit are 200μV to 1mV.

SOURCES OF GENERATED CURRENT ERROR

Errors in current-measuring instruments arise from currents generated in various circuit elements. The current I_M indicated on a current meter is actually equal to the current I_1 through the meter, plus or minus some meter uncertainty U_M (see **Figure 1b**). I_1 is the sum of

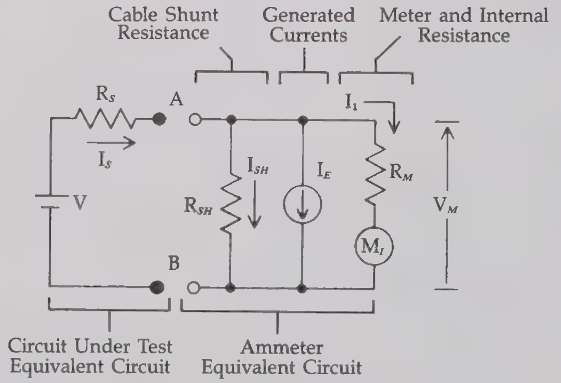
FIGURE 1a



$$I = \frac{V}{R_S}$$

Figure 1a: A source causes a current I to flow through a wire between A and B.

FIGURE 1b



$$\underbrace{I_M}_{\text{Indicated Current}} = \underbrace{\frac{V}{R_S}}_{\text{Current to be Measured}} - \underbrace{\frac{V_M}{R_S}}_{\text{Voltage Burden Error}} - \underbrace{I_{SH}}_{\text{Shunt Current Error}} - \underbrace{I_E}_{\text{Generated Current Error}} \underbrace{\pm\, U_M}_{\text{Meter Uncertainty}}$$

When an ammeter and connecting cable are used in place of a wire between A and B, a voltage burden V_M is developed which forces a shunt current I_{SH} through the shunt resistance R_{SH} of the cable. Unwanted error currents I_E are also generated due to various phenomena discussed in the text.

FIGURE 2: Shunt Ammeter

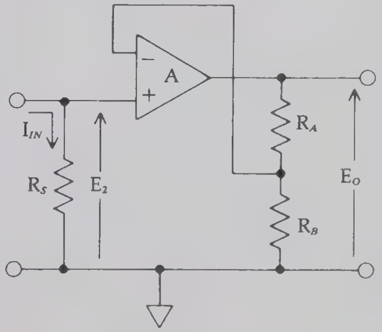
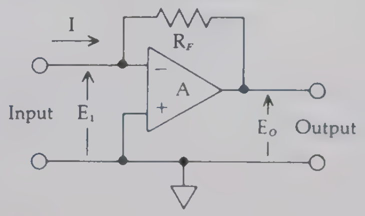


FIGURE 3: Feedback Ammeter



the signal current I_S less shunt current I_{SH} and the sum of all generated currents I_E.

Noise Currents

Current generators at various points in the circuit are summed to form a total error current I_E in **Figure 1b**. These currents may arise from triboelectric, piezoelectric, and electrochemical effects, or resistive leakage. The sum of error currents in the measurement instrument is included in the specifications of the instrument.

Triboelectric currents (**Figure 4**) are generated by charges created at the interface between a conductor and an insulator due to friction. Here, free electrons rub off the insulator and create a charge imbalance that causes the current flow. A typical example would be currents generated by insulators and conductors rubbing together in a coaxial cable.

Piezoelectric currents (**Figure 5**) are generated when mechanical stress is applied to certain insulating materials which generate a charge when stressed. The effect occurs in some ceramics and other crystalline materials, as well as some plastics used for insulated terminals and interconnecting hardware.

Noise currents also arise form electrochemical effects (**Figure 6**) when ionic chemicals create weak currents between conductors on a substrate. For example, commonly used epoxy printed circuit boards, when not thoroughly cleaned of etching solution, flux, or other material, can generate currents of a few nanoamps between board conductors. To prevent these currents, a cleaning agent such as Freon or methanol should be applied to all interconnecting circuitry.

Current is also generated by thermal activity in the shunt resistance. This current is given by:

$$I = \sqrt{4kTF/R}$$

where K is Boltzmann's constant, T is temperature in °K, F is noise bandwidth, and R is the resistance value. Generally, this current can be ignored when measuring above 10^{-14}A.

Figure 7 summarizes approximate magnitudes of the various current generating effects.

FIGURE 4: Triboelectric Effect

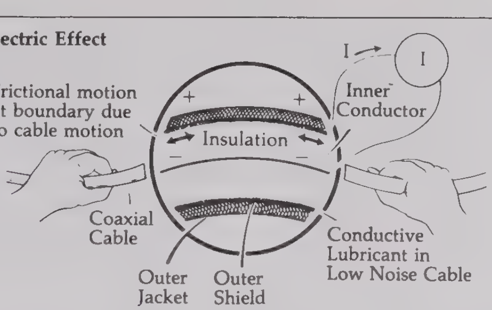

I
I
Frictional motion at boundary due to cable motion
+
+
Inner Conductor
Insulation
−
−
Coaxial Cable
Conductive Lubricant in Low Noise Cable
Outer Jacket
Outer Shield

FIGURE 5: Piezoelectric Effect

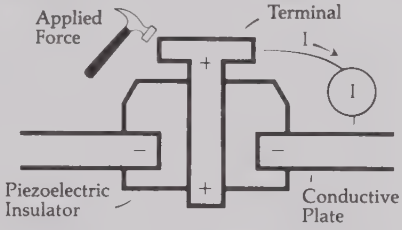

Applied Force
Metal Terminal
I
+
I
−
−
+
Piezoelectric Insulator
Conductive Plate

FIGURE 6: Electrochemical Effects

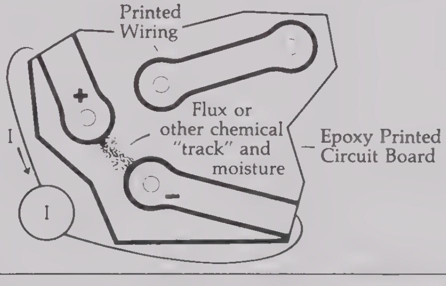
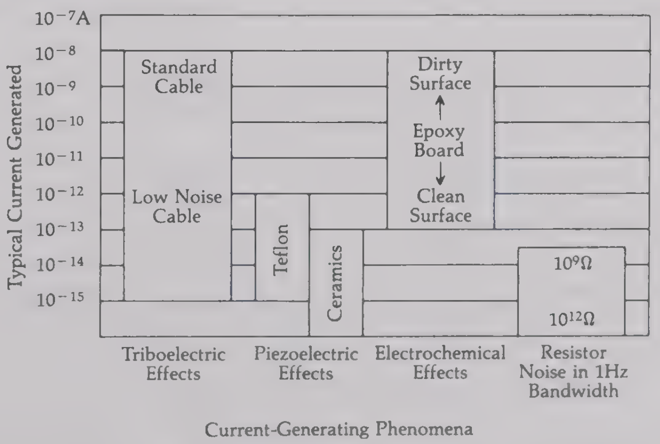

Printed Wiring
+
I
Flux or other chemical "track" and moisture
Epoxy Printed Circuit Board
−
I

FIGURE 7: Typical Magnitudes of Current Generated Due to Low Current Phenomena



HIGH RESISTANCE MEASUREMENTS

Low current measurement techniques must often be used to determine the value of high resistances. In some cases a constant voltage technique is used. Here, a constant voltage source is impressed across the resistance to be measured, and the resulting current is read from a series ammeter to indicate resistance. This measurement technique provides the advantage of rigidly defining the voltage used in the test. Test voltage is an important parameter for many measurements, because high resistance values often depend on applied voltage.

Figure 8 shows a different high-resistance measurement technique, using a constant current passing through the resistance to be measured. The resulting voltage across the resistance is then measured by an electrometer—a high-resistance voltmeter. These techniques are also often used for measuring semiconductor I vs. V characteristics and for measuring breakdown voltage curves.

Typical multifunction electrometers designed for these measurements can measure resistances up to $2\times10^{14}\Omega$, low currents down to 10^{-15}A, voltages up to 200V with input resistances greater than $10^{14}\Omega$, and charge to 10^{-14} coulombs.

Shunt resistance in high-resistance measurements is usually limited by the resistance of the cabling and interconnection hardware. The resistance of particular insulatorsthat may contribute to this shunt resistance depends on insulator surface conditions, moisture content, and temperature. For example, ceramic insulators cleaned with methanol which have not been touched may have $10^{14}\Omega$ or $10^{15}\Omega$ resistance. But these same insulators may degrade to $10^{11}\Omega$ or $10^{12}\Omega$ if they develop hairline cracks or if they accumulate a surface film such as that acquired from sitting in a dirty atmosphere for months.

Typical resistance values of various insulating materials are shown in **Figure 9**. Absorbed moisture may also change the resistance of certain insulators by orders of magnitude. A qualitative description of water absorption, piezoelectric, and triboelectric properties of various insulators is given in **Table 1.**

Guarding and Capacitive Effects

To minimize shunt currents, most electrometer amplifiers include a guard connection to their amplifier outputs. This guard connection makes the voltage drop across insulators located between the input and the guard equal to the output voltage divided by the amplifier gain, thus reducing the voltage stress across the insulator to nearly zero.

One additional source of error in high-resistance measurements is capacitance normally associated with cables and connectors. At high resistance levels, even a few picofarads of capacitance can create appreciable time constants. For example, a $10^{12}\Omega$ resistance and a cable capacitance of 100pF has an RC time constant of 100 seconds. However, use of guarding and feedback techniques will reduce this capacitance. Amplifier gain is normally in the range of 10^4 to 10^6. The effective input capacitance will be the unfedback input capacitance divided by this value.

SUMMARY

The feedback ammeter circuit used in electrometers and picoammeters reduces errors in low current measurements by reducing the voltage drop at the ammeter, which also reduces voltage stress on the interconnecting cabling and measurement time constant. If sources of unwanted generated currents due to triboelectric, piezoelectric, electrochemical, and Johnson noise phenomena are understood, they can be reduced to acceptable levels. High resistance measurements can be made using either constant-voltage or constant-current methods; the 617 electrometer can use either method.

FIGURE 8: High Resistance Measurement Using Constant Voltage or Constant Current Method

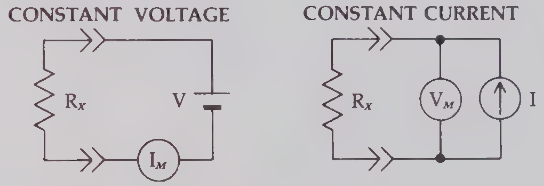


FIGURE 9: Approximate Resistances of Various Insulating Materials

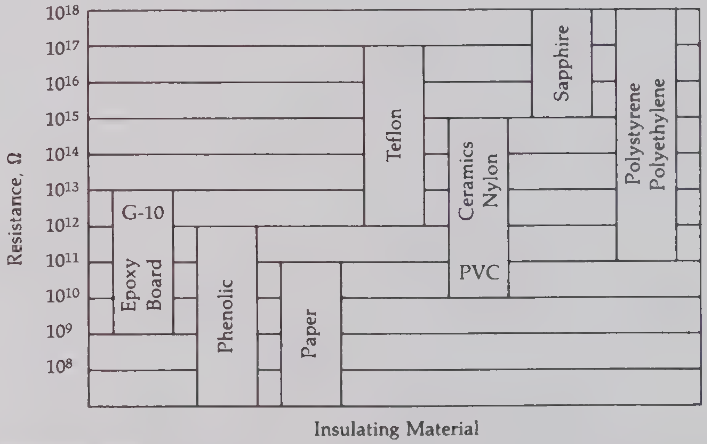


TABLE 1: Insulating Characteristics of Various Insulating Materials

Volume Resistivity (Ohm-cm)	Material	Property Resistance to Water Absorption	 Minimal Piezoelectric Effects	 Minimal Triboelectric Effects
10^{16} - 10^{18} Ω	Sapphire	+	+	0
10^{17} - 10^{18} Ω	Teflon®	+	–	–
10^{14} - 10^{18} Ω	Polyethylene	0	+	0
10^{12} - 10^{18} Ω	Polystyrene	0	0	–
10^{17} - 10^{18} Ω	Kel-F®	+	0	–
10^{12} - 10^{14} Ω	Ceramic	–	0	+
10^{12} - 10^{14} Ω	Nylon	–	0	–
10^{10} - 10^{17} Ω	Glass Epoxy	–	0	–
10^{10} - 10^{15} Ω	PVC	+	0	0
10^{5} - 10^{12} Ω	Phenolic	–	+	+

KEY: + Material very good in regard to the property
0 Material moderately good in regard to the property
– Material weak in regard to the property

ELECTROMETER/PICOAMMETER APPLICATIONS

Measuring FET Gate Leakage and Channel Current (Figure 10)

It is often important to measure gate leakage or channel leakage in MOSFETs, JFETs, analog switches, multiplexer circuits, and other circuits. Electrometers can measure sensitive levels of current, voltage, or charge in these tests. In the circuits shown, either a Model 617 with its built-in voltage cource or a Model 230 voltage source with an electrometer or picoammeter may be used.

Beam Experiments (Figure 11)

Sensitivity and precision are vital for a variety of beam experiments and will enhance the performance of mass spectrometers, electron microscopes, and other analytical equipment involving beams of charged particles. The sensitivity of electrometers and picoammeters makes them especially useful in these experiments.

The same characteristics ae needed for other measurements of charge, charge flow, and related phenomena in the research lab, such as ionization currents, ion chamber outputs, dielectric absorption in insulators, thermally induced currents, radiation studies, etc.

Resistance Measurement Using A Constant Current Source (Figure 12)

This is the simplest form of resistance measurement. Merely connect the resistance to the input and the electrometer displays the value. Test currents are selected with the OHMS range selection. The voltage across the resistor is read directly at the display or bus output.

A Model 220 I source and an electrometer in the VOLTAGE mode may be used for this measurement, providing more selectability of the current source.

Resistance Measurement Using A Voltage Source (Figure 13)

In this mode, the test voltage is controlled by the 617's programmable V source or a separate Model 230 V source. Since high resistance values are often quite dependent on the impressed stress voltage, voltage control can be crucial to obtaining valid data. The 617 V source may be selected over the range of ±100V in 50mV steps; the 230 V source goes to 50μV per step.

I-V Curve: Source I, Read V (Figure 14)

The OHMS function of electrometers is a current source and a high-impedance voltmeter. It may be used to directly determine I-V characteristics, using decade current steps. A Model 220 I source may be used to provide settability from 0.5pA/step.

I-V Curve: Source V, Read I (Figure 15)

The AMPS mode of an electrometer may be used in conjunction with the 617's programmable V source or a separate Model 230 V source to develop a detailed I-V characteristic. Either directly on the display or via the IEEE-488 bus, you set the source to the desired voltage and read the current. The 617's voltage source goes to 100V in 50mV steps; the Model 220 provides settability from 50μV/step.

FIGURE 10: Measuring FET Gate Leakage and Channel Currents

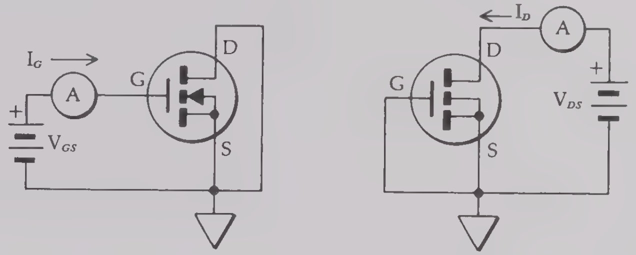


FIGURE 11: Beam Experiments

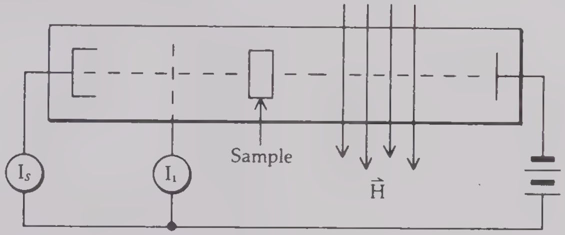
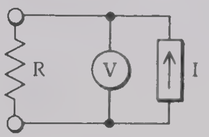


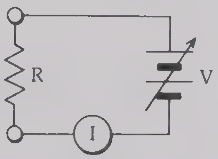
FIGURE 12: Resistance Measurement Using a Current Source



V is measured. Electrometer display indicates:

$R = V \times \frac{1}{I}$ ohms.

FIGURE 13: Resistance Measurement Using a Voltage Source



I is measured. Model 617 displays V/I ohms.

FIGURE 14: I-V Curve: Source I, Read V

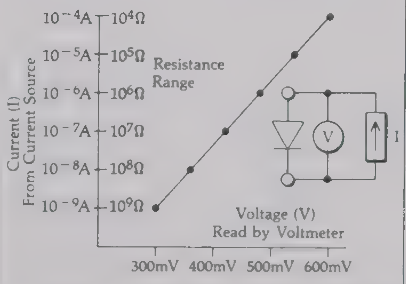
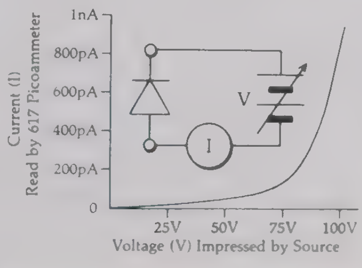


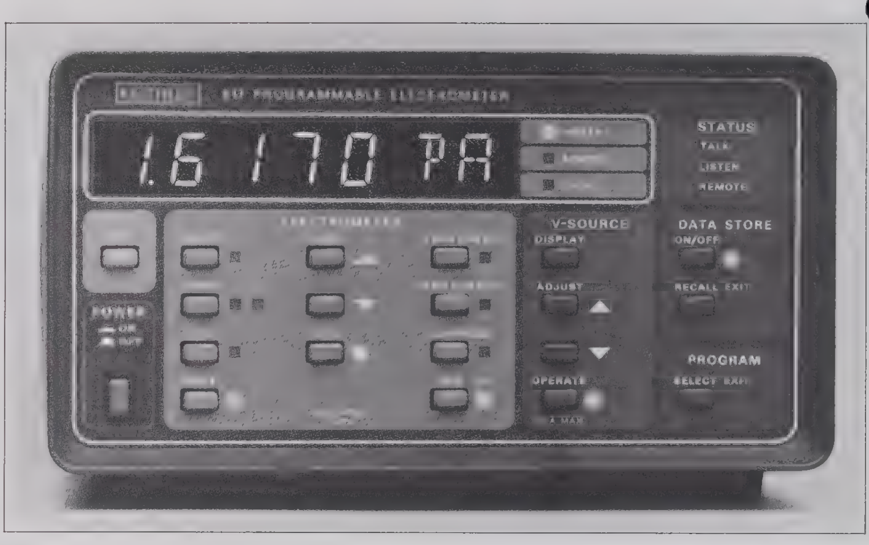
FIGURE 15: I-V Curve: Source V, Read I

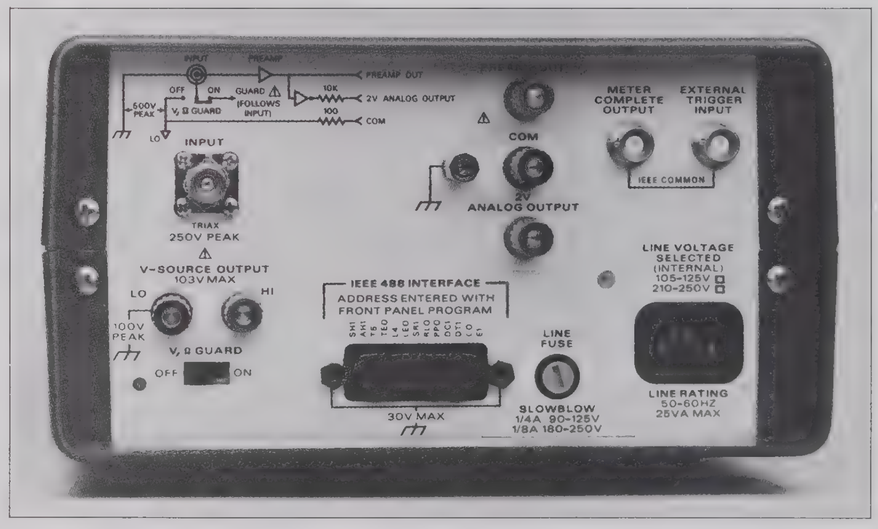


617/Electrometer-Source

10^{-15}A Sensitivity, 10^{-16}A/Count, $10^{16}\Omega$

- **Built-in V source**
- **Full autoranging**
- **Built-in IEEE-488 interface**
- **Built-in V-Ω Guard**
- **Data storage**


617 PROGRAMMABLE ELECTROMETER
1.6170 PA
STATUS
TALK
LISTEN
REMOTE
V-SOURCE
DISPLAY
ADJUST
OPERATE
DATA STORE
ON/OFF
RECALL EXIT
PROGRAM
SELECT EXIT
POWER


INPUT
PREAMP
PREAMP OUT
OFF
ON
GUARD
(FOLLOWS INPUT)
500V PEAK
V, Ω GUARD
LO
10K
2V ANALOG OUTPUT
100
COM
INPUT
TRIAX
250V PEAK
V-SOURCE OUTPUT
103V MAX
LO
HI
100V PEAK
V, Ω GUARD
OFF
ON
COM
2V
ANALOG OUTPUT
METER COMPLETE OUTPUT
EXTERNAL TRIGGER INPUT
IEEE COMMON
IEEE 488 INTERFACE
ADDRESS ENTERED WITH FRONT PANEL PROGRAM
SH1 AH1 T6 TE0 L4 LE0 SR1 RL0 PP0 DC1 DT1 C0 E1
30V MAX
LINE FUSE
SLOWBLOW
1/4A 90-125V
1/8A 180-250V
LINE VOLTAGE SELECTED (INTERNAL)
105-125V
210-250V
LINE RATING
50-60HZ
25VA MAX

Rear panel of Model 617 Electrometer/ Source has all inputs and outputs as well as V-Ω Guard switch and standard IEEE-488 interface connection.

The Model 617 Programmable Electrometer is our latest and most advanced electrometer. It is a sensitive, versatile, 4½-digit, 7-function instrument which includes a bipolar 100V voltage source, a decade current source, IEEE-488 interface, and outstanding low current accuracy specifications. It has better specifications, superior capabilities, and is essentially the same price as our Model 616, the standard sensitive dc meter in most scientific and engineering laboratories for over 10 years.

The 617 can measure resistances or generate I-V curves using either of two measurement techniques. Using the 1nA to 100μA decade current source, a known constant current is forced through the unknown resistance (see Figure 12 on page 35). The developed voltage is measured with a high input impedance voltmeter, and the resistance or voltage is displayed and transmitted over the IEEE-488 bus. Alternatively, the 617's programmable voltage source is applied across the unknown and the resulting current is detected by the 617's sensitive current circuitry (see Figure 13 on page 35). Current may be displayed directly, or resistances as high as $10^{16}\Omega$ can be directly measured; the 617 can calculate and display the quantity V/I. Since the resistance of most high resistance materials is a function of the applied voltage, the controlled voltage technique provides better characterization of these materials.

The 617's built-in IEEE-488 interface makes all controls programmable. You get full autoranging over the full span of ranges on voltage, current, charge, and resistance functions. And you can choose your format for the front panel readout: either exponential or engineering units.

The JFET input gives you lower voltage noise and more immunity to overload, without sacrificing current sensitivity.

Pushbutton suppression lets you make relative measurements with respect to a selected baseline, or cancel background signals. ZERO CORRECT cancels internal offsets at the touch of a button. Both are bus programmable.

The built-in V-Ω GUARD switch lets you drive the inner shield of the triaxial input cable at guard voltage, minimizing leakage current and time constants. 100-point data storage is also built in, with Min/Max readings available from front panel or bus.

For all its precision and performance, the 617 is extremely easy to operate. Its DMM-like controls and clear 4½-digit display let you handle a variety of applications quickly and easily. And, like a DMM, the 617 features simple Digital Calibration. It also has real-time input and output triggers for communication with other instrumentation.

The unprecedented performance of the 617 gives you much higher value than even the proven 616: there is no price premium for all the added capabilities.

Electrometer-Source/617

10^{-15}A Sensitivity, 10^{-16}A/Count, $10^{16}\Omega$

VOLTS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C
200 mV	10 µV	0.05 + 4	0.004 + 3
2 V	100 µV	0.05 + 1	0.004 + 0.3
20 V	1 mV	0.05 + 1	0.005 + 0.1
200 V	10 mV	0.07 + 4	0.007 + 0.1

*When properly zeroed.

NMRR: >80dB on 200mV, 60dB on 2V and 20V, 55dB on 200V range, at 50Hz or 60Hz ±0.1%.

CMRR: >120dB at dc, 50Hz or 60Hz.

INPUT IMPEDANCE: >200TΩ in parallel with 20pF (<2pF guarded).

GAIN ERROR AT PREAMP OUTPUT: Typically 5ppm.

SMALL SIGNAL BANDWIDTH AT PREAMP OUTPUT: Typically −3dB at 100kHz.

AMPS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C
2 pA	100 aA	1.6 + 66	0.15 + 8
20 pA	1 fA	1.6 + 7	0.15 + 1
200 pA	10 fA	1.6 + 1	0.15 + 0.1
2 nA	100 fA	0.25 + 5	0.015 + 3
20 nA	1 pA	0.25 + 1	0.015 + 0.3
200 nA	10 pA	0.25 + 1	0.015 + 0.1
2 µA	100 pA	0.15 + 4	0.005 + 3
20 µA	1 nA	0.15 + 1	0.005 + 0.3
200 µA	10 nA	0.15 + 1	0.006 + 0.1
2 mA	100 nA	0.15 + 4	0.005 + 3
20 mA	1 µA	0.15 + 1	0.005 + 0.3

*When properly zeroed.

INPUT BIAS CURRENT: <5fA (5×10^{-15}A) at 23°C.

INPUT VOLTAGE BURDEN: <1mV except 3mV on 20mA range.

PREAMP SETTLING TIME (to 1% of final value): 2.5s on pA, 15ms on nA, 5ms on µA and mA ranges.

NMRR: >95dB on pA, 60dB on nA, µA, and mA ranges at 50Hz or 60Hz ±0.1%.

COULOMBS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C
200 pC	10 fC	0.4 + 4	0.02 + 3
2 nC	100 fC	0.4 + 1	0.02 + 0.3
20 nC	1 pC	0.4 + 1	0.02 + 0.1

*When properly zeroed.

INPUT BIAS CURRENT: <5fA (5×10^{-15}A) at 23°C.

OHMS

RANGE	RESOLUTION	ACCURACY (1 Yr.)* 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	TEST CURRENT ±1.5%
2 kΩ	100 mΩ	0.20 + 4	0.01 + 3	100 µA
20 kΩ	1 Ω	0.15 + 1	0.01 + 0.3	100 µA
200 kΩ	10 Ω	0.25 + 1	0.01 + 0.3	10 µA
2 MΩ	100 Ω	0.25 + 1	0.02 + 0.3	1 µA
20 MΩ	1 kΩ	0.25 + 1	0.02 + 0.3	100 nA
200 MΩ	10 kΩ	0.30 + 1	0.02 + 0.3	10 nA
2 GΩ	100 kΩ	1.5 + 1	0.04 + 0.3	1 nA
20 GΩ	1 MΩ	1.5 + 1	0.04 + 0.1	1 nA
200 GΩ	10 MΩ	1.5 + 1	0.04 + 0.1	1 nA

Up to 10,000TΩ (10PΩ) can be measured using the V/I mode.

*When properly zeroed.

MAXIMUM OPEN CIRCUIT VOLTAGE: 300V dc.

PREAMP SETTLING TIME (To 0.1% of final reading, with <100pF input capacitance): 2kΩ through 20MΩ: 15ms; 200MΩ: 150ms. **(To 1% of final value with Input Guard on and <1pF of unguarded input capacitance):** 2GΩ: 10ms; 20GΩ: 100ms; 200GΩ: 1s.

V/I MODE

Used with V source; displays resistance (5×10^{4} to $10^{16}\Omega$) calculated from measured current. V/I Ohms accuracy equal to accuracy of V source plus accuracy of selected amps range.

VOLTAGE SOURCE

OUTPUT: −102V to +102V in 50mV steps.

ACCURACY (1 Yr., 18°-28°C): ±(0.2% + 50mV).

TEMPERATURE COEFFICIENT: ±(0.005% + 1mV)/°C.

MAXIMUM OUTPUT CURRENT: ±2mA; active current limit at <4mA with annunciation.

SETTLING TIME: <3ms to rated accuracy.

NOISE: <(1ppm of output voltage + 200µV) p-p from 0.1Hz to 10Hz.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Function, Range, Zero Check, Zero Correct, Zero Suppress, EOI, Trigger, Terminator, 100-Reading Storage and Retrieval, Calibration, V Source Output, Display Format, SRQ, Status (including V Source I-Limit), Output Format.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

TRIGGER TO READING DONE: 350ms typical.

GENERAL

DISPLAY: 4½-digit numeric LEDs with appropriate decimal point and polarity indication; signed two-digit alphanumeric exponent.

OVERRANGE INDICATION: Display reads "OL".

RANGING: Automatic or manual.

CONVERSION TIME: 330ms.

DATA STORE and MIN/MAX: 100-reading store capacity; records data at one of six selectable rates fromevery reading to 1 reading/hour, or by manual triggering. Also detects and stores maximum and minimum readings continuously while in the Data Store mode.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

MAXIMUM INPUT: 250V peak, dc to 60Hz sine wave; 10s per minute maximum on mA ranges.

MAXIMUM COMMON MODE VOLTAGE (dc to 60Hz sine wave): Electrometer, 500V peak; V Source, 100V peak.

ISOLATION (Input LO to chassis): Typically $10^{10}\Omega$ in parallel with 500pF.

INPUT CONNECTOR: Two lug triaxial on rear panel.

OUTPUT CONNECTORS: 5-way binding posts on rear panel for V source, preamp, and analog outputs. Rear panel BNC for External Trigger and Meter Complete.

2V ANALOG OUTPUT: 2V for full range input. Inverting in Volts and Ohms modes. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Volts and Ohms measurements. Can be used as an inverting output or with external feedback in Amps and Coulombs modes. Output impedance 100Ω.

EXTERNAL TRIGGER: TTL compatible External Trigger and Electrometer Complete.

V, Ω GUARD SWITCH: OFF position: Inner shield of triax is Input LO, input capacitance is ≤20pF. ON position: Inner shield of triax is Guard (follows input HI). Input capacitance is ≤2pF. Use Analog Output COM for for Input LO connection.

ENVIRONMENT: Operating: 0°-50°C, relative humidity 70% non-condensing, up to 35°C. **Storage:** −25° to +65°C.

SHIELDING: Double shielded.

WARMUP: 2 hours to rated accuracy.

POWER: 105-125V or 210-250V (internal switch selected), 90-110V available; 50-60Hz, 25VA.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.6kg (8 lbs.).

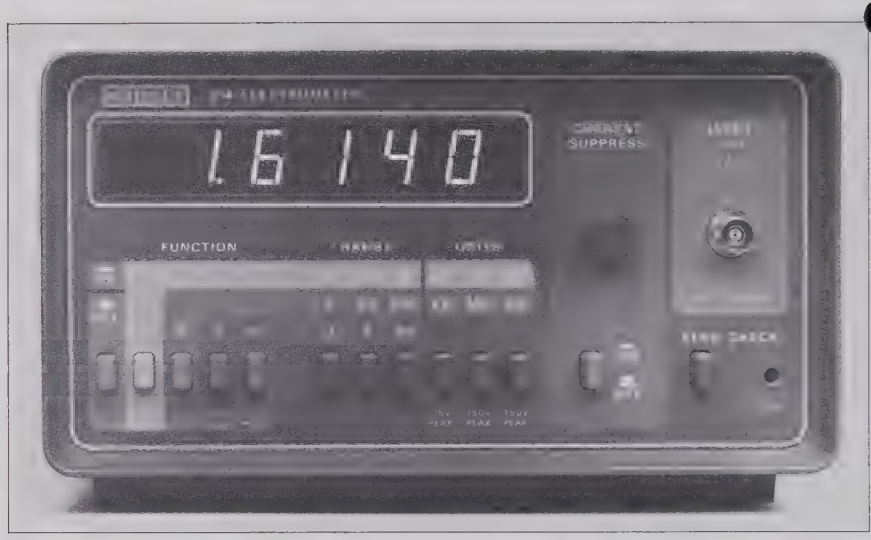
ACCESSORY SUPPLIED: Model 6011 Triaxial Input Cable.

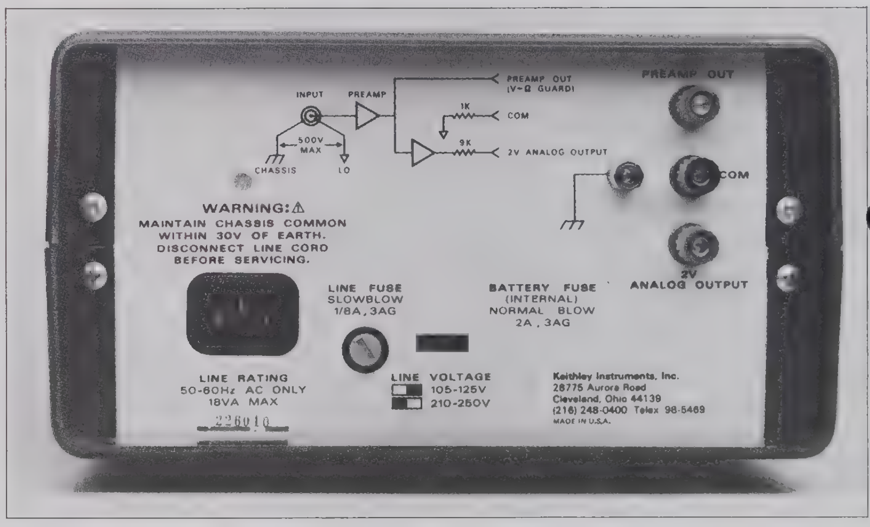
ACCESSORIES AVAILABLE: See Selector Guide on page 49.

614/Electrometer

Economical

- **4½-digit LED display**
- **10^{-14}A sensitivity**
- **Current suppression**
- **5 × 10^{13}Ω input impedance**


1.6140
SUPPRESS
FUNCTION


INPUT
PREAMP
PREAMP OUT (V-Ω GUARD)
1K
COM
9K
2V ANALOG OUTPUT
500V MAX
CHASSIS
LO
WARNING: ⚠
MAINTAIN CHASSIS COMMON WITHIN 30V OF EARTH. DISCONNECT LINE CORD BEFORE SERVICING.
PREAMP OUT
COM
2V ANALOG OUTPUT
LINE FUSE SLOWBLOW 1/8A, 3AG
BATTERY FUSE (INTERNAL) NORMAL BLOW 2A, 3AG
LINE RATING 50-60Hz AC ONLY 18VA MAX
226010
LINE VOLTAGE
105-125V
210-250V
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400 Telex 98-5469
MADE IN U.S.A.

Rear panel of Model 614 Electrometer.

The Model 614 is an optimum synthesis of careful design, basic simplicity, quality components, and pragmatic performance capabilities. It makes the difficult job of sensitive measurements as easy as operating a DMM, yet it is extremely sensitive and affordable.

Pushbutton Easy. The handsome appearance of the 614 is an example of form following function. The pushbutton configuration is precise, simple, quick, and easy to use. Color-coded range and function selection is as functional as it is attractive. The front panel is designed to be legible with a large 4½-digit LED display and clear legends for all functions.

Battery/Line. For isolation from ac line interference, the 614 features a built-in, rechargeable lead-acid battery pack. The pack provides over 10 hours of off-line operation, automatically recharges when the power line is plugged in, and automatically cuts in should line power be interrupted.

Flexible & Convenient. The 614 rear panel includes two analog outputs: a 2V output for recorders and a preamp output for use as a driven guard with the 6167 guarded input adapter. The CURRENT SUPPRESS feature allows background currents to be zeroed out at the touch of a button. Durable construction and a full range of capabilities assure a long and cost-effective life cycle.

Sensitive Performer. The 614 performs four functions: current, resistance, voltage, and charge measurements. It is capable of detecting currents as low as 10^{-14}A and resistances up to $2\times10^{11}\Omega$. It provides more than $5\times10^{13}\Omega$ input impedance on the voltage ranges, and can detect charge over a range of 10^{-14} to 2×10^{-8}C. It is appropriate for a wide range of applications in component and circuit testing as well as in research and student laboratories.

Budgetable. Our optimal design approach to the Model 614 allowed us to reduce production costs without sacrificing the sophisticated performance capabilities traditional with electrometers. The combination of modern components and assembly techniques, as well as high reliability based on a JFET front end, keep the cost of the Model 614 low and assure a high return on your investment.

VOLTS

RANGE	RESOLUTION	ACCURACY (1 Year)* 18°-28°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C
0.2 V	10 µV	0.08 + 2*	0.005 + 2
2 V	100 µV	0.08 + 2	0.005 + 0.2
20 V	1 mV	0.08 + 1	0.005 + 0.1

*When properly zeroed.

NMRR: >60dB at 50Hz and 60Hz.

CMRR: >120dB at dc, 50Hz and 60Hz.

INPUT IMPEDANCE: $>5\times10^{13}\Omega$ in parallel with 20pF.

MAXIMUM OVERLOAD: 350V peak.

AMPS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	MAXIMUM SUPPRESSION
20 pA	10 fA	1.5 + 5*	0.1 + 1	± 20 pA
200 pA	100 fA	1.5 + 3	0.1 + 0.3	±200 pA
2 nA	1 pA	1.5 + 1	0.1 + 0.3	±200 pA
20 nA	10 pA	0.5 + 2	0.02 + 0.3	± 20 nA
200 nA	100 pA	0.5 + 1	0.02 + 0.3	±200 nA
2 µA	1 nA	0.5 + 1	0.02 + 0.3	±200 nA
20 µA	10 nA	0.3 + 2	0.01 + 0.3	± 20 µA
200 µA	100 nA	0.3 + 1	0.01 + 0.3	±200 µA
2 mA	1 µA	0.3 + 1	0.01 + 0.3	±200 µA

*When properly zeroed.

INPUT BIAS CURRENT: <60fA at 23°C.

INPUT VOLTAGE BURDEN: <200µV.

PREAMP SETTLING TIME (to 1% of final value): 0.6s on pA, 5ms on nA, 2.5ms on µA ranges.

NMRR: 70dB on pA and nA ranges; 55dB on µA ranges. At 50Hz and 60Hz.

MAXIMUM OVERLOAD: 350V peak on pA and nA ranges; 75V peak on µA ranges.

COULOMBS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg + counts)
0.2 nC	10 fC	5 + 50
2 nC	100 fC	5 + 5
20 nC	1 pC	5 + 1

INPUT BIAS CURRENT: <60fA at 23°C.

MAXIMUM OVERLOAD: 350V peak.

OHMS

RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	TEST CURRENT
2 kΩ	1 Ω	0.5 + 2	0.03 + 0.3	100 µA
20 kΩ	10 Ω	0.5 + 2	0.03 + 0.3	100 µA
200 kΩ	100 Ω	0.5 + 2	0.03 + 0.3	10 µA
2 MΩ	1 kΩ	0.8 + 2	0.04 + 0.3	100 nA
20 MΩ	10 kΩ	0.8 + 2	0.04 + 0.3	100 nA
200 MΩ	100 kΩ	0.8 + 2	0.04 + 0.3	100 nA
2 GΩ	1 MΩ	2.0 + 3	0.12 + 0.3	100 pA
20 GΩ	10 MΩ	2.0 + 2	0.12 + 0.3	100 pA
200 GΩ	100 MΩ	2.0 + 2	0.12 + 0.3	100 pA

MAXIMUM OPEN CIRCUIT VOLTAGE: 32V dc.

MAXIMUM OVERLOAD: 75V peak on kΩ ranges; 350V peak on MΩ and GΩ ranges.

GENERAL

DISPLAY: Five LED digits with appropriate decimal point, polarity, and overload indication.

CURRENT SUPPRESS: Active in Current mode; allows correction for input currents on any given range.

CONVERSION TIME: 400ms.

2V ANALOG OUTPUT: 2V out for full range input. Inverting in Voltage and Resistance modes. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Voltage and Resistance measurements. Can be used as an inverting output or with external feedback in Current and Coulombs modes. Output impedance 1kΩ.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

CONNECTORS: Input: Triax. **Output:** 5-way binding posts.

ENVIRONMENT: Operating: 0°-35°C, up to 70% relative humidity. **Storage:** −25° to +65°C.

POWER: Line or battery operated. 105-125V or 210-250V (switch selected), 90-110V available. 50-60Hz, 5VA typical; 18VA maximum during battery charge. 10 hour operation from full charge, 20 hours to recharge.

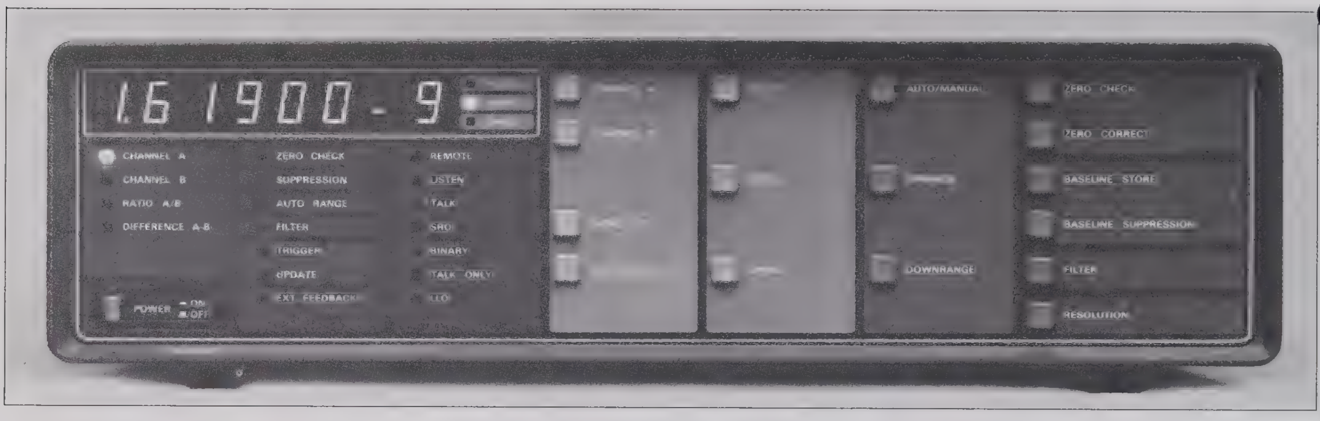
DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.3kg (7.2 lbs.).

ACCESSORY SUPPLIED: Model 6011 Triaxial Input Cable.

ACCESSORIES AVAILABLE: See Selector Guide on page 49.

619/Electrometer

Dual Channel


1.61900-9
CHANNEL A
CHANNEL B
RATIO A/B
DIFFERENCE A-B
ZERO CHECK
SUPPRESSION
AUTO RANGE
FILTER
TRIGGER
UPDATE
EXT. FEEDBACK
REMOTE
LISTEN
TALK
SRQ
BINARY
TALK ONLY
LLO
POWER ON/OFF
AUTO/MANUAL
DOWNRANGE
ZERO CHECK
ZERO CORRECT
BASELINE STORE
BASELINE SUPPRESSION
FILTER
RESOLUTION

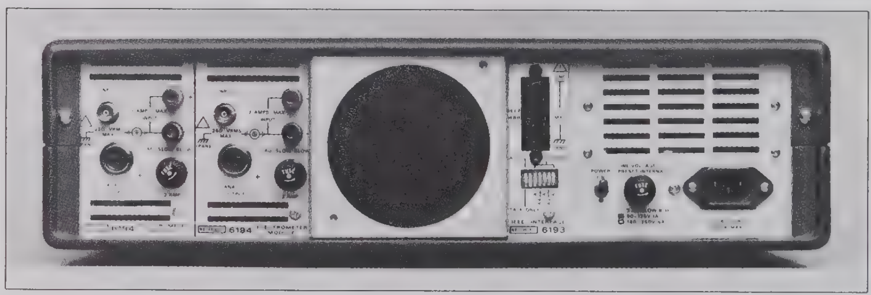
- **Current measurement from 10fA to 2A dc**
- **Voltage measurement from 1μV to 200V dc with 20TΩ input resistance**
- **Resistance measurements from 10mΩ to 2TΩ**
- **Optional dual channels and IEEE-488 interface**

The 619 provides researchers, semiconductor designers, and component evaluators with two independent, separately programmable 5½-digit measurement channels, each with 1μV dc, 10fA dc, and 10mΩ sensitivities.

System Compatibility. Keithley designed the 619 to be a convenient and easily reconfigurable programmable instrument:

- Dual channels allow measurements at each node of a device without using switching systems that degrade the signal.
- EXTERNAL TRIGGER initiates a measurement. An ELECTROMETER COMPLETE signal is issued at the end of the measurement.
- Data Store capability allows storage of up to 50 readings.

Guarding and Fast Sensitive Measurements. The 619 uses feedback circuitry pioneered by Keithley for low current measurements. In the AMPS mode, the HI input is held within 1mV of circuit LO on the 2nA through 20mA ranges. This provides a convenient GUARD point (circuit LO) and minimizes the charge stored in connecting cables, permitting fast measurements in an automatic system.



Rear panel of Model 619 Electrometer/ Multimeter shows optional second channel (Model 6194) and IEEE-488 Interface (Model 6193) installed.

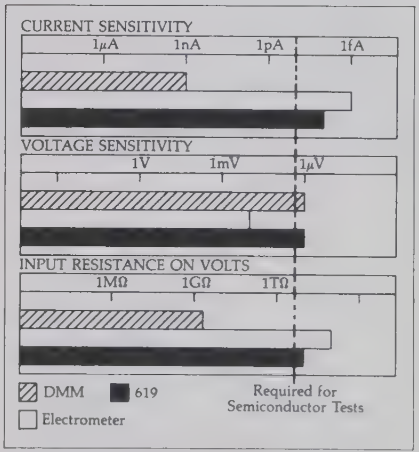
Ratio, Difference. Computes the ratio (A/B) or difference (A – B) of the readings from each channel.

External Feedback. An EXTERNAL FEEDBACK range may be selected to permit measurements of charge, logarithmic currents, or other special current-to-voltage relationships, depending on the device installed as the feedback element.

Baseline Store, Baseline Suppress. Touching BASELINE STORE will save the displayed reading in the memory. The BASELINE SUPPRESS button will then modify all future readings (on any range within that function) by subtracting the stored value.

Filter. Selection activates a low-pass filter for additional line frequency or noise rejection on a selected channel.

Digital Self Test. Digital Self Test on power up checks the RAM, ROM, circuit board configuration, and optoisolators.



Full range bipolar current gain characteristics and leakage measurements are facilitated by fA sensitivity.

1μV dc resolution allows lower level current forcing which minimizes self heating in van der Pauw measurements.

High input impedance enables measurements of gate voltages on MOSFETs.

DC VOLTS

RANGE	MAXIMUM READING	ACCURACY (1 Year)* 23° ±5°C ±(%rdg + counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C
200 mV	199.999×10^{-3}	0.01 + 25	0.002 + 30
2 V	1.99999	0.01 + 10	0.002 + 3
20 V	19.9999	0.02 + 10	0.002 + 0.3
200 V	199.999	0.02 + 10	0.002 + 0.3

INPUT CAPACITANCE: ≤20pF.

INPUT RESISTANCE: ≥20TΩ.

NMRR: >55dB (>80dB with FILTER).

CMRR: >100dB (>125dB with FILTER).

ANALOG SETTLING TIME (to 0.1% of final value, unfiltered): <5ms.

DC AMPS

RANGE	MAXIMUM READING	ACCURACY (1 Year) 23° ±5°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	INVERTING FULL SCALE ANALOG OUTPUT
2 nA	1.99999×10^{-9}	0.35 + 65	0.02 + 30	0.2 V
20 nA	19.9999×10^{-9}	0.35 + 35	0.02 + 3	2.0 V
200 nA	199.999×10^{-9}	0.15 + 25	0.01 + 30	0.2 V
2 μA	1.99999×10^{-6}	0.15 + 10	0.01 + 3	2.0 V
20 μA	19.9999×10^{-6}	0.15 + 25	0.01 + 30	0.2 V
200 μA	199.999×10^{-6}	0.15 + 10	0.01 + 3	2.0 V
2 mA	1.99999×10^{-3}	0.15 + 25	0.01 + 30	0.2 V
20 mA	19.9999×10^{-3}	0.15 + 10	0.01 + 3	2.0 V
2 A	1.99999	0.15 + 25	0.01 + 20	None

INPUT VOLTAGE DROP: <1mV at full scale except <0.6V on 2A range.

ANALOG SETTLING TIME (to 0.1% of final value, unfiltered): 2nA through 2μA ranges: 50ms. 20μA through 2A ranges: 5ms.

NMRR: 2nA through 2μA ranges: 70dB. 20μA through 2A ranges: 55dB.

OHMS

RANGE	MAXIMUM READING	ACCURACY (1 Year) 23° ±5°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg+counts)/°C	MAXIMUM OPEN CIRCUIT VOLTAGE
2 kΩ	1.99999×10^{3}	0.2 + 25	0.01 + 30	5V
20 kΩ	19.9999×10^{3}	0.2 + 10	0.01 + 3	5V
200 kΩ	199.999×10^{3}	0.15 + 25	0.01 + 30	5V
2 MΩ	1.99999×10^{6}	0.15 + 10	0.01 + 3	5V
20 MΩ	19.9999×10^{6}	0.35 + 25	0.02 + 30	5V
200 MΩ	199.999×10^{6}	0.35 + 10	0.02 + 3	5V
2 GΩ	1.99999×10^{9}	0.35 + 10	0.02 + 0.3	300V
20 GΩ	19.9999×10^{9}	1 + 10	0.15 + 3	300V
200 GΩ	199.999×10^{9}	4 + 10	0.5 + 0.3	300V
2 TΩ	1.99999×10^{12}	10 + 25	0.5 + 0.3	300V

OHMS CURRENT SOURCES: 2kΩ, 20kΩ: 100μA.
200kΩ, 2MΩ: 1μA.
20MΩ, 2GΩ: 10nA.
20GΩ through 2TΩ: 100pA.

ANALOG OUTPUT: Analog output voltage level is the product of the ohms current source and the resistance being measured.

ANALOG SETTLING TIMES:

To 0.1% of final value, unfiltered, with <100pF input capacitance:	2kΩ through 2MΩ: 5ms. 20MΩ: 20ms. 200MΩ: 200ms.
To 10% of final value, unfiltered, using 6191 Guarded Input Adapter with <1pF unguarded input capacitance:	2GΩ: 150ms. 20GΩ: 1.5s. 200GΩ: 15s. 2TΩ: 150s.

IEEE-488 BUS IMPLEMENTATION (Option 6193):

MULTILINE COMMANDS: DCL, LLO, SDC, GET.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN. Compatible with IEEE-488-1978 standard.

PROGRAMMABLE PARAMETERS: Front Panel Controls: Function, Range, Filter, Zero Check, Zero Correct, Basline Store, Baseline Suppress. **Internal Parameters:** SRQ Response, Trigger Modes, Binary or ASCII Data Formats, number of readings to be stored, Data Terminators, Reading Rates, Integration Period.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

GENERAL

DISPLAY: Numeric; 0.56 in. LED digits, 4½-digit mantissa @ 6.2 rdg./s (5½ digits @ 2.4 rdg/s in high resolution mode), 2-digit exponent; decimal point, signed exponent and mantissa.

OVERRANGE INDICATION: Display reads OFLO.

MAXIMUM ALLOWABLE INPUT: 250V rms, dc to 60Hz sine wave.

INTERNAL CURRENT (18°-28°C): <0.4pA.

EXTERNAL TRIGGER: TTL compatible EXTERNAL TRIGGER and ELECTROMETER COMPLETE.

INPUT CONNECTORS (6194 Electrometer rear panel): 2A range: 5-way binding posts. All other functions and ranges via Teflon insulated triaxial connector.

OUTPUT CONNECTORS: Analog: Amphenol Series 80 (microphone), 6194 Electrometer rear panel. **IEEE:** Amphenol or Cinch Series 57, 6193 IEEE Interface rear panel. BNC (chassis isolated) connections for EXTERNAL TRIGGER and ELECTROMETER COMPLETE.

READING RATES:

Programmed Reading Rate	Number Of Integrations Averaged	Time Per Integration (ms)	Trigger To First Byte* (ms)	Readings Per Second
S0	1	4.1	32 (18 binary)	40
S1	1	16.67**	35	21
S2	2	16.67**	80	10
S3	4	16.67**	168	5.4
S4	1	100.1	120	4.7
S5	2	100.1	328	2.4
S6	4	100.1	742	1.2
S7	8	100.1	1680	0.6
S8	16	100.1	3360	0.3
S9	32	100.1	6720	0.15

*Typical. Add an additional 42ms for first conversion on a new channel, 26ms for first conversion on a new range or function.

**20 @ 50Hz.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGES:
Input LO (Ch.A) to line ground: 250V rms, dc to 60Hz sine wave.
Input LO (Ch.B) to line ground: 250V rms, dc to 60Hz sine wave.
Input LO (Ch.A) to Input LO (Ch.B): 250V rms, dc to 60Hz sine wave.

WARMUP: 1 hour to rated accuracy.

POWER: 90-110, 105-125, 180-220, or 210-250V, (internal switch selected), 50 or 60Hz, 75W max., 100VA max. (internally fan cooled).

ENVIRONMENTAL LIMITS: Operating: 0°-50°C, up to 35°C at 70% non-condensing R.H. **Storage:** −20° to 70°C.

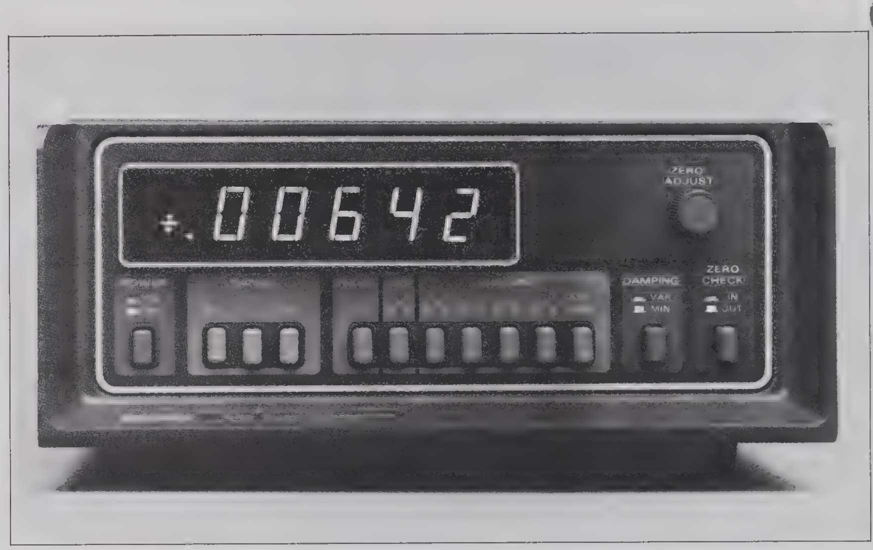
DIMENSIONS, WEIGHT: 432mm wide × 127mm high × 406mm deep (17 in. × 5 in. × 16 in.), stackable enclosure. Net weight 9.8kg (22 lbs.) with Channel B Electrometer module and IEEE-488 Interface module.

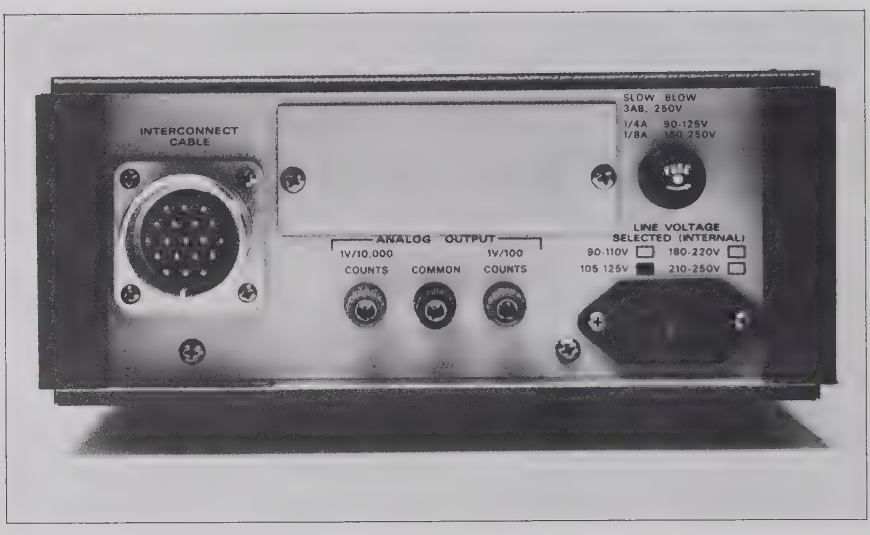
ACCESSORIES SUPPLIED: One Model 6194 Electrometer Module, one Model 6011 Input Cable, analog output connectors.

ACCESSORIES AVAILABLE: See Selector Guide on page 49.

642, 642 LNFPA/Electrometer

10^{-17}A





Rear panel of Model 642 Electrometer.

- **10^{-17}A (10aA) sensitivity**
- **Over 100:000:1 linear dynamic range at analog output**
- **Fast response: 22ms time constant on 10^{-10}A range**

The Keithley 642 is a direct reading MOSFET-based electrometer for sensitive measurement of current, voltage, or charge. Its current measurement range is 10aA to 200nA with typically less than 1mV voltage burden. Voltage reading capabilities are 10μV to 10V with 10,000TΩ input resistance. Charge can be measured from 800aC to 100pC. Maximum sensitivity is obtained when using the CHARGE mode to integrate current applied to the input.

High Resolution. The digital format permits observation of small changes in large signals with resolution to 1 part in 20,000 at the digital display. The FEEDBACK output has low noise and non-linearity of only about 5ppm. This wide dynamic range (from noise level to maximum output) provides constant gain over the full span, and eliminates the need for range changing.

State-of-the-Art Design. The 642 uses a specially packaged dual monolithic MOSFET with compensated temperature coefficient in a guarded package. Variations in ambient temperature do not cause significant errors because compensation circuitry is individually adjusted for each FET to give a voltage coefficient of only 30μV/°C.

In the design of the remote head, the active input volume has been minimized. Less than 15 ionization current pulses per hour are observed.

The preamplifier is a direct-coupled circuit with a single, well-controlled time constant. It is a first-order system which produces an exponential response to step inputs. Response time can be varied over a 100:1 span on the 10^{-12}A range.

The remote head is sealed and contains desiccant paper to maintain low internal humidity. Internal humidity can be observed on an indicator on the bottom of the remote head.

The ZERO CHECK switching mechanism has been designed for minimum charge transfer, typically less than 10fC. Internal adjustments may be used to further compensate the average charge transfer.

Analog Outputs. Three analog outputs are provided: The FEEDBACK output on the remote head has the most precision and and widest dynamic range (over 10^5), lowest noise, and fastest speed. The 1V/10,000 COUNTS output on the rear of the mainframe normalizes the output to 1V per 10,000 counts regardless of range. The 1V/100 COUNTS output (also on the rear panel) is useful in sensitive measurements to amplify the signal so that 1V corresponds to 100 counts.

Accessories. Input connections are described on the Input Connection Chart. In addition, an isolated BCD output option (Model 6422), IEEE-488 output (Model 6423), 12V battery adapter (Model 6428), and individually sealed desiccant paper refills (Model 6421) are available.

AS A DC AMMETER

CURRENT SETTING	MAXIMUM READING ON 0.1 RANGE	MAXIMUM READING ON 10 RANGE
10^{-8} A	0.19999×10^{-8} A	10.9999×10^{-8} A
10^{-10} A	0.19999×10^{-10} A	10.9999×10^{-10} A
10^{-11} A	0.19999×10^{-11} A	10.9999×10^{-11} A
10^{-12} A	0.19999×10^{-12} A	10.9999×10^{-12} A

CURRENT SETTING	ACCURACY (6 Mo.) 23°C ±1°C ±(%rdg + counts)	1% SETTLING TIME ON 10 RANGE AT 1V/10k COUNTS ANALOG OUTPUT, AT MINIMUM DAMPING
10^{-8} A	1 + 3	≤ 40 ms
10^{-10} A	1 + 3	≤100 ms
10^{-11} A	1.3 + 3	≤400 ms
10^{-12} A	1.5 + 6	≤ 5 s

NOISE: 4×10^{-17}A rms (2×10^{-16}A p-p); <15 self-generated alpha pulses per hour.

AS A DC VOLTMETER

RANGE	READING	ACCURACY (6 Mo.) 18°-28°C (Exclusive of Noise) ±(%rdg + counts)	1% SETTLING TIME AT 1V/10k COUNTS ANALOG OUTPUT
0.1 V	.19999	0.5 + 3	3 s
1 V	1.9999	0.05 + 1	0.3 s
10 V	10.999	0.05 + 1	0.03 s

NOISE: <20μV rms (100μV p-p).

ZERO STABILITY: 24 hours, ±3°C: ±180μV.

TEMPERATURE COEFFICIENT OUTSIDE OF ±3°C SPAN: ±(30μV + 0.5 count)/°C.

INPUT RESISTANCE: $\geq 10^{16}\Omega$.

AS A COULOMBMETER

RANGES: 10^{-11} coulombs, 0.1, 1, or 10 ranges.

INPUT CURRENT (23°C ±1°C): $<5 \times 10^{-17}$A.

ACCURACY (23°C ±1°C for 6 months, exclusive of noise): ±(0.3% + 5 counts).

NOISE: 8×10^{-16} coulombs rms (4×10^{-15} coulombs p-p), 0.1 range; <15 self-generated alpha pulses per hour.

CHARGE ERROR DUE TO ACTUATION OF ZERO CHECK: Typically $<10^{-14}$ coulombs.

GENERAL

MAXIMUM INPUTS: Normal or Common Mode: 30V rms, dc to 60Hz.

DISPLAY: Five 0.5 in. LED digits with decimal point and polarity indication.

CONVERSION PERIOD FOR DIGITAL DISPLAY: 400ms.

ANALOG OUTPUTS: Two analog outputs are provided on mainframe rear panel: 1V/10,000 counts and 1V/100 counts of the digital display.

POWER REQUIREMENTS: 90-110V, 105-125V, 120-220V, or 210-250V; 50 Hz to 60Hz, 30VA maximum.

DIMENSIONS, WEIGHTS:

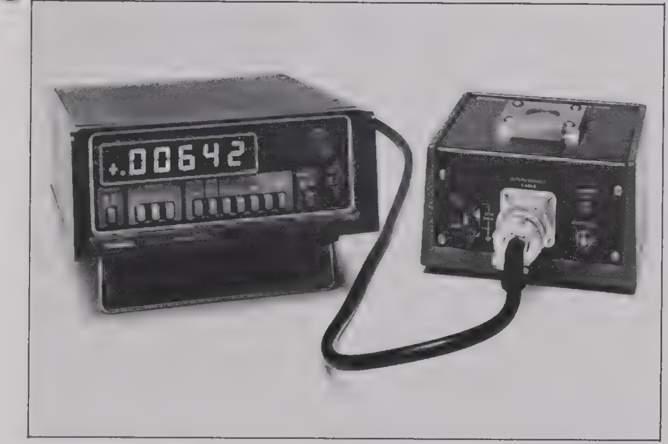
MAINFRAME: 3½ in. half rack, 100mm high × 217mm wide × 308mm deep (4 in. × 8½ in. × 12⅛ in.). Net weight 2.9kg (6 lbs., 6 oz.).

REMOTE HEAD: 102mm high × 162mm wide × 165mm deep (4 in. × 6⅜ in. × 6½ in.), exclusive of connectors. Net weight 4.1kg (9 lbs., 2 oz.).

INTERCONNECT CABLE: 4 ft. long. Net weight 0.6kg (1 lb., 3 oz.).

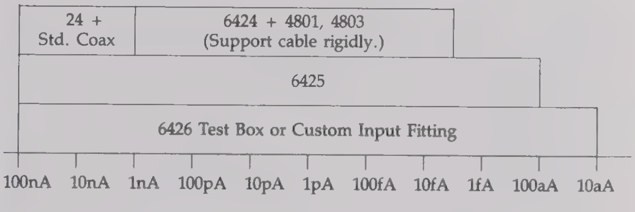
ACCESSORY SUPPLIED: Four-foot remote head to mainframe interconnect cable.

ACCESSORIES AVAILABLE: See Selector Guide on page 49.



642 Remote Head is sealed and contains desiccant paper to maintain low internal humidity.

Input Connection Chart, showing recommended input connections for various current sensitivities:



642 LNFPA

In precision ratio isotope mass spectrometry, the sensitivity and linearity of the 642 are essential. However, the standard unit may not be fast enough to settle to within 0.01% of final value in the short time the beam remains stable. Also, precision requirements often demand lower noise per unit bandwidth to obtain sufficiently repeatable results.

The 642 LNFPA was developed for these demanding situations. Typically, it will settle to within 0.01% of final value in 2 seconds or less on the 10^{-11}A range, allowing most of the time the beam is stable for integration of the signal from the precision FEEDBACK output. It also has a selected lower noise input FET. Noise is documented and <50μV (vs. the standard 100μV) in the VOLTAGE mode, reducing the effective noise current on the 10^{-11}A range.

602/Electrometer

Floating

Electrometer/**610C**

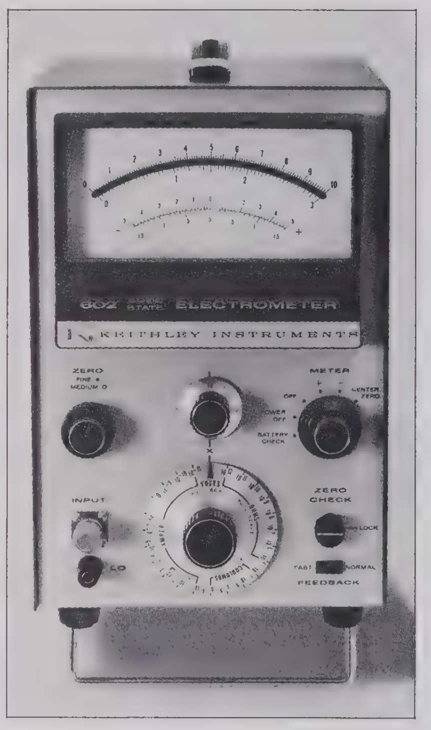
Line Operated

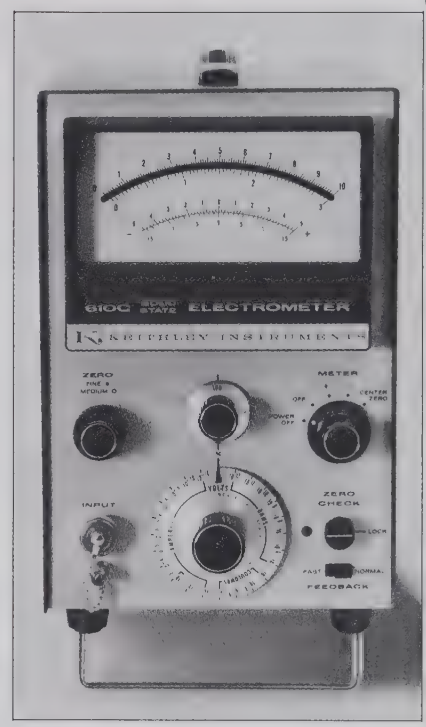
602:

- **Battery operated: 1000 hours life**
- **1500V floating capability**
- **5×10^{-15}A input current**
- **Measures V, I, R, Q, and is a current source**

610C:

- **5×10^{-15}A input current**
- **$10^{14}\Omega$ input resistance to 100V**
- **Measures V, I, R, Q, and is a current source**





The battery-operated Model 602 and the line-operated Model 610C electrometers are analog instruments with a wide range of capabilities. The 610C is a grounded-input instrument which has wider voltage, resistance, and charge ranges, but the 602 adds battery-operated convenience and ±1500V off-ground capability.

An important feature of these units is the low input current of 5×10^{-15}A which minimizes zero offset with high source resistances and permits maximum resolution when measuring current and charge.

To optimize measurement results under different conditions, two measuring modes are provided: shunt (NORMAL) which provides selectable input resistance on VOLTS, or feedback (FAST) which provides low input voltage as an ammeter or coulombmeter.

AS VOLTMETERS

RANGE: 602: 0.001V full scale to 10V in nine 1× and 3× ranges. **610C:** 0.001V full scale to 100V in eleven 1× and 3× ranges.

ACCURACY: ±1% of full scale on all ranges, exclusive of noise and drift.

ZERO DRIFT: $<$1mV per 24 hours; $<150\mu$V per °C.

METER NOISE: $\pm 25\mu$V max. with input shorted on most sensitive range.

INPUT IMPEDANCE: $>10^{14}\Omega$ shunted by 20pF. Input resistance may also be selected in decade steps from 10 to $10^{11}\Omega$.

AS AMMETERS

RANGE: 10^{-14}A full scale to 0.3A in twenty-eight 1× and 3× ranges.

ACCURACY: ±2% of full scale on 0.3 to 10^{-11}A ranges using smallest available multiplier setting; ±4% of full scale on 3×10^{-12} to 10^{-14}A ranges.

METER NOISE: $< \pm 3 \times 10^{-15}$A. **OFFSET CURRENT:** $< 5 \times 10^{-15}$A.

AS AMPLIFIERS

INPUT IMPEDANCE: $>10^{14}\Omega$ shunted by 20pF. Input resistance may also be selected in decade steps from 10 to $10^{11}\Omega$.

UNITY GAIN OUTPUT: At dc, output = input within 10ppm, exclusive of noise & drift, for output currents $\leq 100\mu$A. Up to 1mA may be drawn for input voltages $\leq$10V. Output polarity is the same as input polarity.

VOLTAGE RECORDER OUTPUT: 602: ±1V for full scale input. Internal resistance is 910Ω. Output polarity is opposite input polarity. **610C:** ±3V for full scale input. Internal resistance is 3kΩ. Output polarity is opposite input polarity.

GAIN: 602: 0.1, 0.33, etc. to 1000. **610C:** 0.3, 0.1, etc. to 3000.

FREQUENCY RESPONSE (within 3dB): dc to 40kHz at gain of 1 and lower, decreasing to dc to 100Hz at maximum gain. Full output response limited to 3kHz on any gain.

CURRENT RECORDER OUTPUT: ±1mA for full scale input, variable ±5% with 1400Ω recorders.

AS OHMMETERS

RANGE: 602: 100Ω full scale to $10^{13}\Omega$ in 23 linear 1× and 3× ranges. **610C:** 100Ω full scale to $10^{14}\Omega$ in 25 linear 1× and 3× ranges.

ACCURACY: 602: ±3% of full scale on 100 to $10^{9}\Omega$ ranges using largest available multiplier setting; 5% of full scale on 3×10^{10} to $10^{13}\Omega$ ranges. **610C:** ±3% of full scale on 100 to $10^{10}\Omega$ ranges using largest available multiplier setting; ±5% of full scale on 3×10^{10} to $10^{14}\Omega$ ranges.

AS COULOMBMETERS

RANGE: 602: 10^{-13}C full scale to 10^{-6}C in fifteen 1× and 3× ranges. **610C:** 10^{-13}C full scale to 10^{-5}C in seventeen 1× and 3× ranges.

ACCURACY: ±5% of full scale on all ranges. Drift due to offset current $\leq 5 \times 10^{-15}$C per second.

GENERAL

POLARITY: Meter switch selects left-zero (positive or negative) or center-zero scales. Output polarity is not reversed.

CONNECTORS: Input (602): Teflon-insulated triaxial. **Input (610C):** Teflon-insulated UHF; ground binding post. **LO (602):** Binding post. **Voltage or current output:** Amphenol 80-PC2F. **Unity gain output, chassis ground:** Binding posts.

POWER: 602: Six 2N6 (or 246, VS305, NEDA 1602); one RM-1W. 1000 hours battery life. Battery conditions may be checked at front panel. **610C:** 105-125V or 210-250V (switch selected), 50-60Hz, 10W.

LINE STABILITY (610C): A 10% change in line voltage will cause $<10\mu$V meter deflection on all ranges.

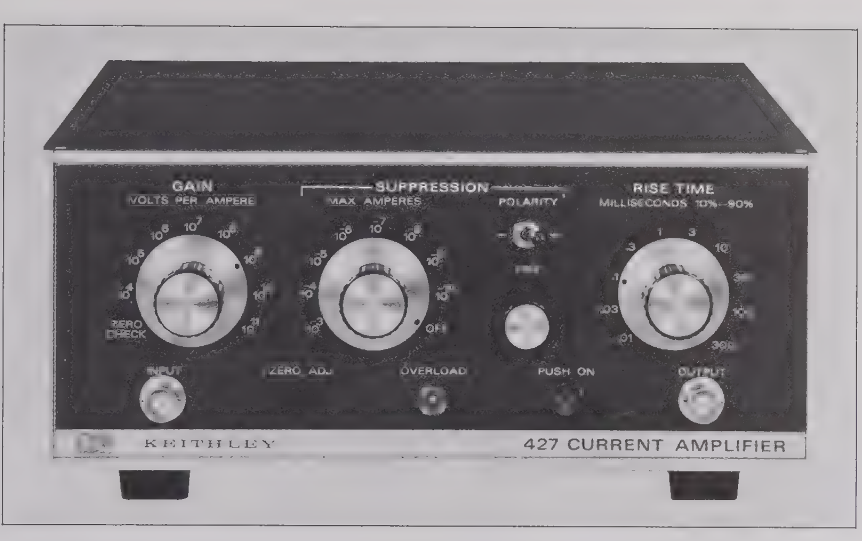
DIMENSIONS, WEIGHT: 275mm high × 175mm wide × 290mm deep (10¾ in. × 7 in. × 11½ in.). Net weight: **602,** 5.7kg (13 lbs.); **610C,** 4.8kg (11 lbs.).

ACCESSORIES SUPPLIED: 602: Model 6011 Input Cable, mating output connector. **610C:** Mating input and output connectors.

ACCESSORIES AVAILABLE: See Selector Guide on page 49.

Current Amplifier/427

- **High speed—as fast as 15µs**
- **Current suppression**
- **Low noise**



The Keithley Model 427 amplifier provides high speed combined with low noise and selectable gain, current suppression, and rise time. It is the fastest Keithley picoammeter, with rise times as fast as 15µs at 10^8V/A gain. Rise times as fast as 1.5ms at the maximum gain of 10^{11}V/A may be selected.

By selecting slower rise times, wider dynamic range and lower noise are obtained: at 10^{11}V/A gain, noise of 3×10^{-15}A rms is achieved, with a dynamic range of 13,000:1.

The built-in current suppression with 10-turn resolution permits compensation of large steady-state currents to observe small changes on a more sensitive range. Eight decade ranges of current suppression are provided, from 10^{-10} to 10^{-3}A.

Transient overloads up to 1000V are absorbed without damage, and to prevent unrecognized distortion, the 427 gives visible indication of all overloads.

These features, plus the 427's combination of speed, dynamic range, and sensitivity, make it extremely useful with scanning electron microscopes, sensitive spectrum analyzers, mass spectrometers, and photomultiplier systems. It is also widely used for measurement of photo effects in biological systems and membrane transport studies, as well as measurement of beam currents and semiconductor properties.

RANGE: 10^4 to 10^{11}V/A in eight decade ranges. (10^{-13}A resolution to 10^{-3}A full output.)

OUTPUT: ±10V at up to 3mA.

OUTPUT RESISTANCE: <10Ω dc to 30kHz.

OUTPUT ACCURACY: ±2% reading up to 10^9V/A range, ±4% of reading on the 10^{10} and 10^{11}V/A ranges exclusive of noise, drift, and current offset.

RISE TIME (10% to 90%): Adjustable in 1× and 3.3× steps from "Fast Rise Time" listed below to 330ms.

NOISE vs. RISE TIME*:

	FAST RISE TIME			WIDE DYNAMIC RANGE		
GAIN V/A	RISE TIME (10%-90%)	DYNAMIC RANGE	NOISE (A RMS)	DYNAMIC RANGE	NOISE (A RMS)	RISE TIME (10%-90%)
10^{11}	1.5 ms	100	4×10^{-13}	1.3×10^4	3×10^{-15}	330 ms
10^{10}	400 µs	200	2×10^{-12}	2×10^4	2×10^{-14}	100 ms
10^9	200 µs	400	1×10^{-11}	2×10^4	2×10^{-13}	10 ms
10^8	60 µs	800	5×10^{-11}	2×10^4	2×10^{-12}	1 ms
10^7	40 µs	2000	2×10^{-10}	2×10^4	2×10^{-11}	100 µs
10^6-10^4	15 µs	2000	—	2×10^4	—	100 µs

*With ≤100pF input shunt capacitance. Noise and/or rise time increase as input shunt capacitance increases (1000pF maximum).

OFFSET CURRENT: $<10^{-12}$A at 25°C and up to 70% relative humidity.

STABILITY: Current offset doubles per 10°C above 25°C. Voltage drift is <0.005%/°C and <0.005% per day of full output after 1-hour warmup.

CURRENT SUPPRESSION: 10^{-10}A to 10^{-3}A in eight decade ranges with 0.1% resolution (10-turn potentiometer). Stability is ±0.2% of suppressed value per °C, ±0.2% per day.

INPUT VOLTAGE DROP: <400µV for full-scale output on 10^6 to 10^{11}V/A ranges when properly zeroed.

EFFECTIVE INPUT RESISTANCE: <15Ω on 10^4 and 10^5 V/A ranges, increasing to <4MΩ on 10^{11}V/A range.

MAXIMUM INPUT OVERLOAD: Transient: 1000V on any range for up to 3 seconds using a Keithley (or other 10mA-limited) high voltage supply. **Continuous:** 500V on 10^{11} to 10^7V/A ranges, decreasing to 200 on 10^6, 70 on 10^5, and 20V on 10^4V/A ranges.

OVERLOAD INDICATION: Lamp indicates pre-filter or post-filter overload.

DYNAMIC RESERVE: 10 (20dB).

CONNECTORS: Input (front): BNC. Output (front and rear): BNC.

POWER: 90-125V or 180-250V (switch selected), 50-60Hz, 5W.

DIMENSIONS, WEIGHT: 100mm high × 220mm wide × 315mm deep (4 in. × 8¾ in. × 12½ in.). Net weight 3kg (7 lbs.).

ACCESSORIES AVAILABLE: See Selector Guide on page 49.

485, 480/Picoammeters

485: Autoranging **480:** LED Display

MODEL 485

- **0.1pA sensitivity**
- **200μV maximum voltage burden**
- **Log I readings**
- **Optional IEEE-488 interface**

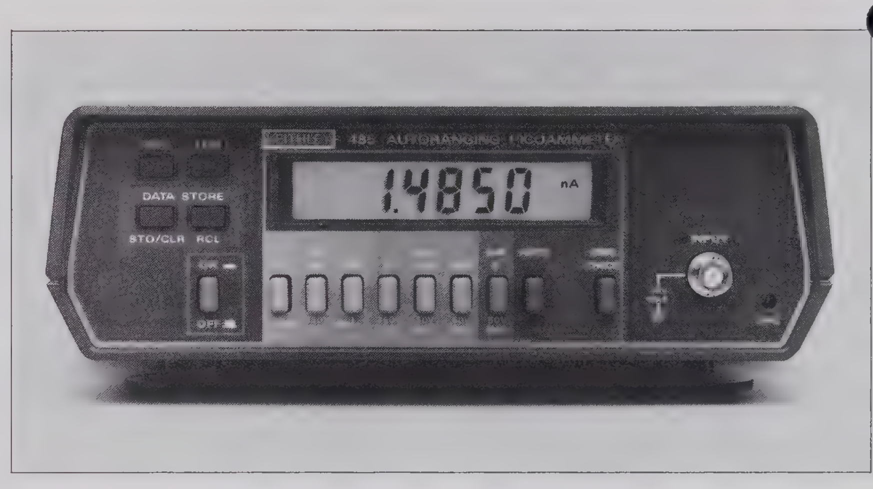
The Model 485 Autoranging Picoammeter provides 0.1pA sensitivity with 4½-digit resolution in a low-cost, highly sensitive, easy-to-use instrument. The 485 measures dc current on seven ranges covering 10 decades from 0.1pA to 2mA. The input can withstand overloads as high as 1000V (with 100kΩ limiting resistor) for flexibility in a wide range of applications in test, research, and student labs. An analog output linearly converts the incoming current to voltage for hard copy output or control loop applications.

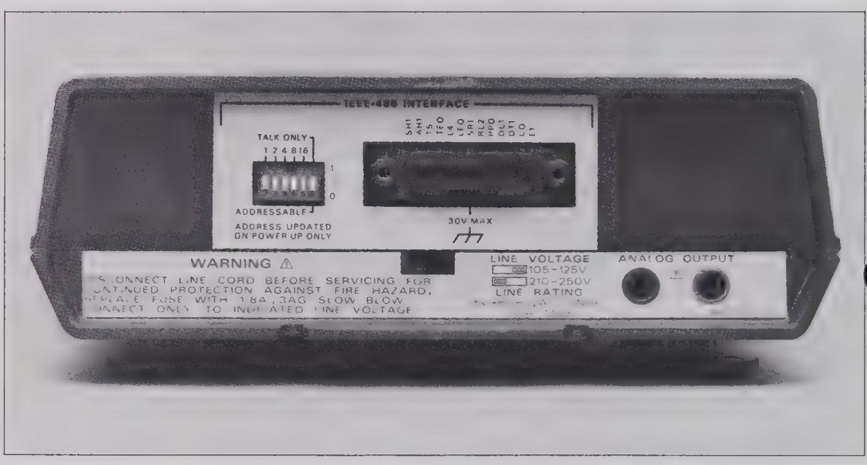
In addition to 0.1pA sensitivity, the 485 has both excellent accuracy and low voltage burden. One-year accuracy on the most sensitive range is an impressive 0.4%. The 485's input voltage drop (burden) is actively constrained by feedback techniques to less than 200μV. Thus the 485 makes high accuracy current measurements even in circuits with very low source voltages.

A microprocessor-based design provides the foundation for a number of the 485's advanced capabilities. In the AUTORANGE mode, the 485 maximizes resolution. The REL button makes readings relative to the baseline (the reading prior to touching the button). The LOG button converts the display to the logarithm (base 10) of the absolute value of the measured current. Digital calibration is accomplished from the front panel or over the bus.

A 100-point DATA STORE buffer collects and stores measurements at one of 6 automatic reading rates from 3 per second to 1 per hour, or manually with the STORE button. Minimum and maximum readings are continuously updated at 3 per second in the DATA STORE mode.

Addition of the Model 4853 IEEE-488 Interface to the 485 adds fully programmable computer control. For isolation from the power line or for portability, the 485 can be battery powered with the Model 1758 Rechargeable Battery Pack.



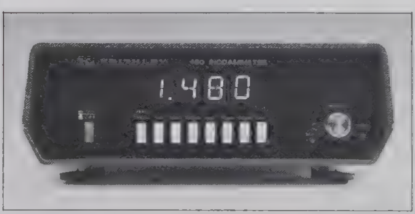


Rear panel of Model 485 Autoranging Picoammeter shows standard analog output and optional Model 4853 IEEE-488 Interface installed.

MODEL 480

- **LED display**
- **1pA resolution**
- **Analog output**
- **Optional IEEE-488 output**

The Model 480 is an easy-to-use, sensitive ammeter that resolves 1pA at a low price. Simple controls, LED display, shielded BNC input, high normal mode rejection, and excellent overload specifications make it easy to use. The 480 measures dc current from 1pA per digit (2nA full range) to 2mA, with 3½-digit precision. Seven ranges cover the full span of low-current measurements. The input is simply connected to the circuit under test, the appropriate range selected, and the current read from the LED display.



LED display makes the 480 a traditional lab favorite in low-light environments.

485: Autoranging 480: LED Display

MODEL 485:

RANGE	RESOLUTION	ACCURACY (1 Year) 18°-28°C ±(%rdg + counts)*	ANALOG RISE TIME (10%-90%)	NORMAL MODE REJECTION RATIO (50 or 60Hz)	MAXIMUM CONTINUOUS INPUT**
2 nA	0.1 pA	0.4 + 4	60 ms	70 dB	350 V dc
20 nA	1 pA	0.4 + 1	60 ms	70 dB	350 V dc
200 nA	10 pA	0.2 + 1	6 ms	65 dB	350 V dc
2 µA	100 pA	0.15 + 1	3 ms	65 dB	350 V dc
20 µA	1 nA	0.1 + 1	3 ms	65 dB	50 V dc
200 µA	10 nA	0.1 + 1	1 ms	65 dB	50 V dc
2 mA	100 nA	0.1 + 1	1 ms	55 dB	50 V dc

*When properly zeroed. **With no limiting resistance: 1000V dc with external 100kΩ series resistance.

MODEL 480:

RANGE	MAXIMUM READING	ACCURACY (1 Year) 18°-28°C ±(%rdg + counts)*	ANALOG RISE TIME (10%-90%)	NORMAL MODE REJECTION RATIO (50 or 60Hz)	MAXIMUM ALLOWABLE INPUT**
1 nA	1.999	0.8 + 4	70 ms	70 dB	600 V dc
10 nA	19.99	0.8 + 3	70 ms	70 dB	600 V dc
100 nA	199.9	0.5 + 3	7 ms	60 dB	600 V dc
1 µA	1.999	0.5 + 3	7 ms	60 dB	600 V dc
10 µA	19.99	0.5 + 3	4 ms	50 dB	75 V dc
100 µA	199.9	0.5 + 3	1 ms	50 dB	75 V dc
1 mA	1.999	0.5 + 3	1 ms	50 dB	20 V dc

*Up to 70% R.H..

INPUT VOLTAGE BURDEN: <200µV.

RANGING: 480: Manual. **485:**Manual or autoranging.

AUTORANGING TIME (485): Average 250ms per range change.

SETTLING TIME AT DISPLAY: <1 second to within 2 counts on fixed range.

CONVERSION PERIOD: 485: 300ms. **480:** 400ms.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-500°C): ±(0.1×applicable accuracy specification)/°C.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, dc to 60Hz sine wave.

ANALOG OUTPUT (485): Output Voltage: +1V = −10000 counts, except +100mV = −10000 counts on 2nA range. **Output Resistance:** 1kΩ.

ANALOG OUTPUT (480): Output Voltage: 1V = 1000 counts. **Output Resistance:** 1kΩ.

REL (485): Pushbutton allows zeroing of on-range readings. Allows relative readings to be made with respect to baseline value. Front panel annunciator indicates REL mode.

DATA STORE and MIN/MAX (485): 100 reading storage capacity; records data at one of six selectable rates from 3 readings/second to 1 reading/hour, or by manual triggering. Also detects and stores maximum and minimum readings continuously while in the DATA STORE mode.

LOG (485): Displays logarithm (base 10) of the absolute value of the measured current (examples: −3.000 = ±1mA; −6.301 = ±0.5µA).

IEEE-488 BUS IMPLEMENTATION (485: Option 4853)

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL2, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Zero Check, REL, LOG, Trigger, Calibration, EOI, SRQ, Status, Output Format, Terminator.

GENERAL

DISPLAY: 485: 4½-digit LCD, 0.5 in. height; polarity, range, and status indication. **480:** Four 0.5 in. LED digits with appropriate decimal point and polarity indication.

OVERRANGE INDICATION: 485: "OL" displayed. **480:** Display blinks all zeros above 1999 counts.

CONNECTORS: Input: BNC. **Analog Output:** Banana jacks.

OPERATING ENVIRONMENT: 0°-50°C, <70% RH up to 35°C; linearly derate 3% RH/°C up to 50°C.

STORAGE ENVIRONMENT: −25° to 60°C.

POWER: 105-125V or 210-250V (switch selected), 90-110V available, 50-60Hz, 12VA (20VA on 480).

DIMENSIONS, WEIGHT: 85mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.). Net weight 1.8kg (4 lbs.).

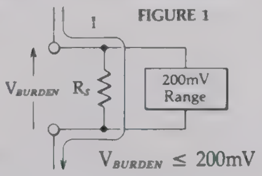
ACCESSORIES AVAILABLE: See Selector Guide on page 49.

VOLTAGE BURDEN CAN CAUSE ERRORS AT ANY CURRENT LEVEL

The voltage burden is the terminal voltage of an ammeter. An ideal ammeter will not alter the current flowing in a circuit when connected in place of a conductor. Thus, it must have zero resistance and therefore zero voltage burden.

Digital multimeters use the shunt ammeter technique shown in **Figure 1** to measure current. The measurement method is to develop a voltage across a sensing resistor. The resistor is chosen such that 200mV corresponds to the maximum current reading on a selected range. The voltage burden specification is the 200mV developed across the sensing resistor.

FIGURE 1



Feedback picoammeters such as the 480/485 and Keithley electrometers use a technique in which the voltage burden is the input voltage of an op amp, as shown in **Figure 2**. The output voltage of the op amp is precisely related to the input current. Since input voltage is output voltage divided by op amp gain (typically 100,000), the voltage burden is only microvolts. Maximum specified voltage burden of the 480/485 is only 0.2mV.

An example of the problems caused by high voltage burden is shown in **Figure 3**. In measuring the emitter current of a transistor, the DMM causes a very significant error (200mV out of 300mV) while the 480/485 voltage burden creates negligible error (0.2mV out of 300mV). Even though the basic measurement is well within the range of a DMM, the 480/485 makes a more accurate measurement since, due to its low voltage burden, the 480/485 is much closer to an ideal ammeter.

FIGURE 2

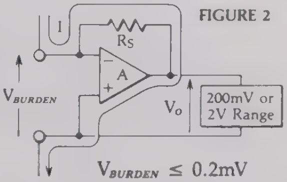
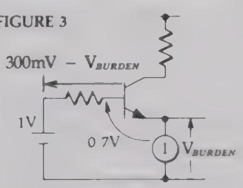


FIGURE 3



Ideal Ammeter: $V_{BURDEN} = 0$
$= 0\%$ Error

480/485: $V_{BURDEN} \leq 0.2mV$
$\leq 0.07\%$ Error

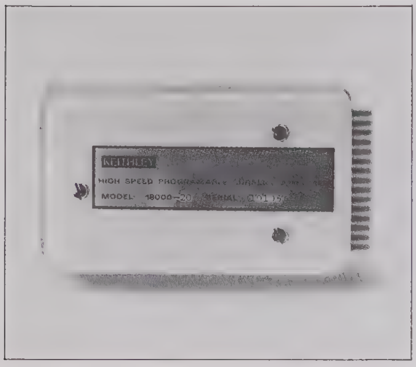
DMM: $V_{BURDEN} \leq 200mV$
$\leq 67\%$ Error

18000-20/Picoammeter

High Speed Amplifier

Picoammeter/26000

Logarithmic

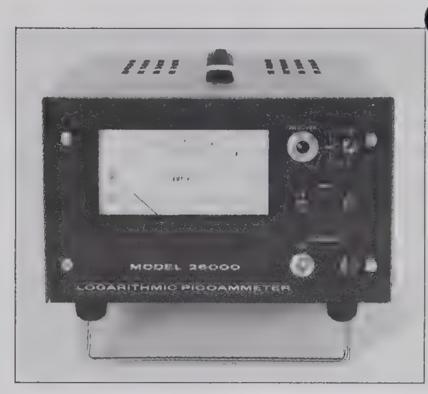


18000-20:

- **Programmable ranges**
- **High speed**
- **Small size**

26000:

- **Logarithmic gain over 6 or 8 decades**
- **Optional positive or negative 300V supply available**



The Model **18000-20** is a versatile, high speed programmable linear picoammeter. It is designed for computer controlled or automated low current measurements where signal lead lengths and physical location are critical factors, and/or it is desired to automatically select current sensitivity. Sensitivity, fast response, stability, and low power consumption make it well suited for custom installation in analytical instruments, nuclear monitoring systems, and component test sets.

Modifications to expand range, increase response speed, or change range selection logic, range combination, and scale factor can custom-tailor the 18000-20 to specific applications.

The Model **26000** Series picoammeters provide logarithmic scales covering a wide range of current without switching. Current measurements are easily performed because the picoammeter can be directly connected to phototubes, photomultipliers, ion vacuum gauges, ion chambers, and automated semiconductor testing equipment.

The 26000 Series provides operational features such as a recover switch that allows quick recovery from large overloads, and a calibration check switch that allows a quick verification of high and low scales. An additional feature consists of a shorting link which may be used to connect input LO to chassis ground.

An internally installed 300V source is available as an option.

Model 18000-20

RANGE: $\pm10^{-10}$A for full output to $\pm10^{-3}$A in decade steps.

RANGE SELECTION: 3-line binary input; "0" (000) corresponds to 10^{-10}A range, "7" (111) correspond to 10^{-3}A range. Logic level is TTL compatible (0=closure to ground, 1=+5V). **Range Switching Time:** <2ms to any range, 10^{-3}A through 10^{-8}A; <10ms to the 10^{-9}A or 10^{-10}A ranges.

RANGE (AMPERE)	RISE TIME (10%-90%)	NOISE P-P (% of full output)
10^{-3}	0.2 ms	0.1%
10^{-4}	0.2 ms	0.1%
10^{-5}	0.2 ms	0.1%
10^{-6}	0.2 ms	0.1%
10^{-7}	0.5 ms	0.1%
10^{-8}	0.5 ms	1.0%
10^{-9}	2.0 ms	2.0% *(typical)
10^{-10}	2.0 ms	

*Typically 3% with 10pF shunting input, 5% at 50pF, increasing to 15% at 500pF. Gain ($\Delta E_{OUT}/\Delta I_{IN}$) is factory adjusted to within 1% of nominal. Internal adjustments are provided for recalibration.

ZERO DRIFT: < ±0.5% of full output per week, noncumulative; better than 0.05% of full output per °C after ½-hour warmup. Voltage offset is adjustable to zero. Offset current is $<10^{-11}$A.

INPUT DROP: <5mV.

MAXIMUM OVERLOAD: Transient: 1000V from a capacitance of 0.01μF. **Continuous:** 30V (or 10mA current from a current-limited supply). Recovery from overload within 10ms.

ANALOG OUTPUT: ±10V at up to 2mA, non-inverting.

CONNECTORS: Input: Microdot S-50Ω series, screw type. **Output:** 15-pin card-edge with 0.156 in. spacing.

POWER: Power requirement is ±15V with 1% regulation. Current consumption is 30mA from +15V supply and 10mA from −15V supply.

DIMENSIONS, WEIGHT: 25mm high × 76mm wide × 127mm deep (1 in. × 3 in. × 5 in.). Net weight 184g (6½ oz.).

ACCESSORIES SUPPLIED: Mating input connector, mating card-edge connector for output, power, and range control.

Model 26000

BASIC MODELS

MODEL NUMBER	RANGE SPAN, AMPERES	DECADE SPAN	CALIBRATION POINTS, AMPERES
26120	10^{-3} to 10^{-11}	8	10^{-4} / 10^{-10}
26220	10^{-4} to 10^{-12}	8	10^{-5} / 10^{-11}
26320	10^{-5} to 10^{-13}	6	10^{-8} / 10^{-11}

TEMPERATURE COEFFICIENT: <2%/°C referred to input current from 10° to 30°C.

RISE TIME: Seconds to 90% of final current value (damping control at minimum setting):

CURRENT CHANGE, AMPERES	CAPACITANCE ACROSS INPUT TERMINALS NONE	5000pF
10^{-12} to 10^{-7}	1 second	2 seconds
10^{-13} to 10^{-12}	3 seconds	6 seconds

LINEAR-LOG RELATIONSHIP:
Ideal: $E_O = M \log I + C$, where M=slope and C=offset of transfer function.
Actual: E_O actual will deviate from the best straight line by <10mV from 10^{-3} to 10^{-11}A; <40mV at 10^{-12}A; <300mV at 10^{-13}A.

RECORDER OUTPUT: 1V/decade from minimum to maximum current.

GROUNDING: Provision is made on rear panel for grounding instrument via a link between low and chassis.

CONNECTORS: Input: BNC type. **Output:** Microphone receptacle, XLR-3-32 (connectors located on rear panel).

POWER: 90-125V or 180-250V, 50-60Hz.

DIMENSIONS, WEIGHT: 140mm high × 222mm wide × 330mm deep (5½ in. × 8¾ in. × 13 in.). Net weight 3.5kg (8 lbs.).

ACCESSORIES SUPPLIED: Set of mating connectors.

OPTIONS AVAILABLE:

MODEL	DESCRIPTION
26X21	Power source installed, +300 volts
26X22	Power source installed, −300 volts

Electrometer/Picoammeter Accessories/**Selector Guide**

	614	619	642	617	602	610C	480	485	427
OUTPUT OPTIONS									
IEEE-488		6193	6423	Standard			1793	4853	
BCD Output			6422				1792		
PROBES									
Static Detector						2503			
High Voltage	6012 6103C	6012 6103C		6012 6103C	6012 6103C	6103C			
CABLES									
Input Cable	6011[1]	6011[1]	6424 4801	6011[1]	6011[1]	19072	4801	4801	4801
Triaxial to Triaxial Cable	7024	7024		7024	7024	7024			
Low Noise Cable Kit							4801	4801	4801
Interconnect Cable			6427						
ADAPTERS									
Triaxial to Coaxial UHF	6012	6012		6012	6012				
Triaxial to BNC	6147	6147		6147	6147				
Triaxial Tee	6146	6146		6146	6146				
Guarded Input	6167	6191		Standard	6167				
3-Slot Male—2-Lug Female Triaxial Adapter	6171	6171		6171	6171				
2-Slot Male—3-Lug Female Triaxial Adapter	6172	6172		6172	6172				
BNC Input			6424						
Air Line Input			6425						
RACK MOUNT KITS									
Single Fixed	1019A-1	1019A	2000	1019A-1			1010	1010	2000
Dual Fixed	1019A-2			1019A-2			1017	1017	
Single Slide	1019S-1	1019S		1019S-1					
Dual Slide	1019S-2			1019S-2					
POWER									
Battery Adapter	N/A[2]		6428		N/A[2]		1788	1758	
TEST BOXES									
Test Shield	6104	6104		6104	6104	6104			
Resistivity Chamber	6105	6105		6105	6105	6105			
Sapphire Insulated			6426						
Guarded High Resistance	8002	8002		8002	8002	8002			
MISCELLANEOUS									
Maintenance Kit		6195							
Electrometer Module		6194							
Desiccant Paper			6421						
Female Triaxial Connector	7023	7023		7023	7023				

See page 85 for descriptions of all accessories.

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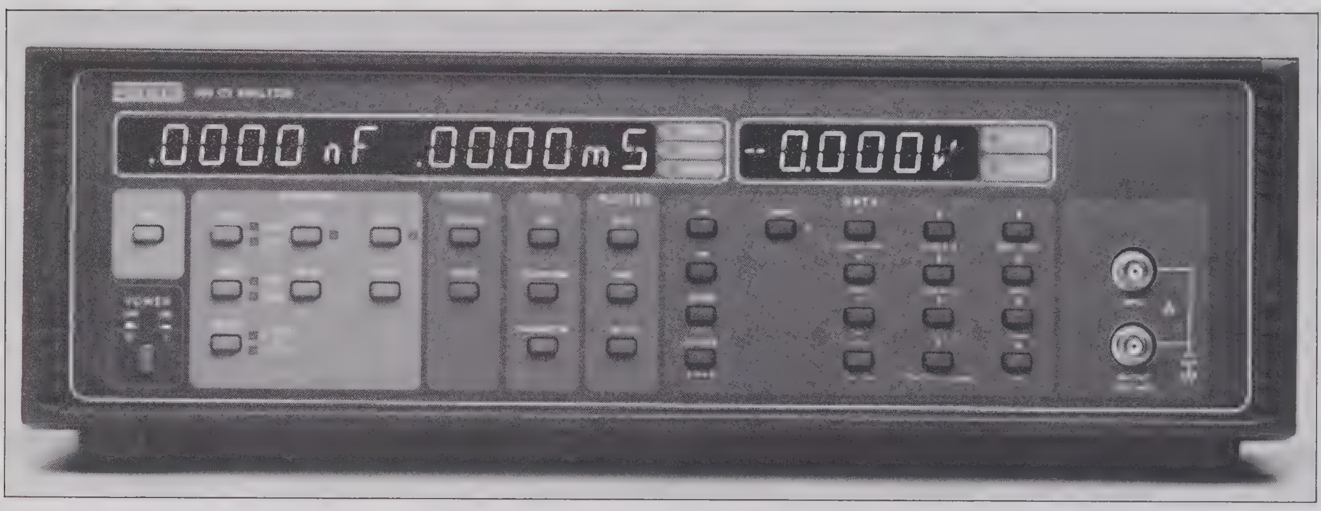
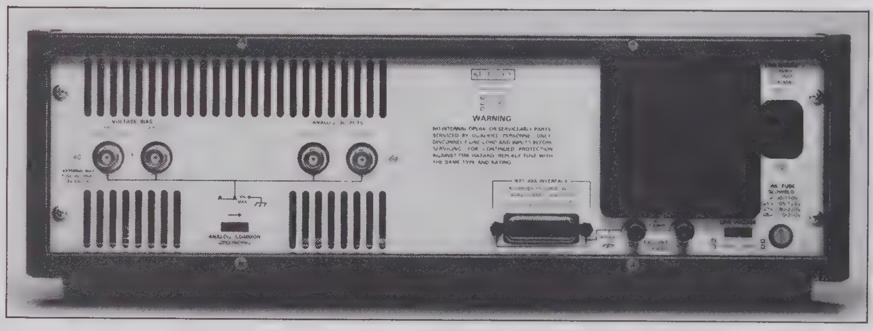
[1] Supplied accessory.

[2] Models 614 and 602 have built-in rechargeable battery packs.

590/CV Analyzer

100kHz and 1MHz C vs. V, G vs. V, or C vs. t Curves





Capability:

- **100kHz, 1MHz, or 100kHz/1MHz test frequencies**
- **Correct for errors induced by connecting cables or switching paths**
- **Internal calculations of C/C_O, $1/C^2$ vs. V, C_A-C_B vs. V, (V_A-V_B) vs. C**
- **Series or parallel model**

...And Convenience:

- **Internally store up to 450 C, G, and V readings in each of 2 buffers**
- **Define your own syntax using TRANSLATOR software**
- **Store your own setups and connection correction parameters**
- **Built-in IEEE-488 interface and plotter drive**

CV Sensitivity and a Choice of Frequencies. The Model 590 is optimized for semiconductor capacitance measurements. It has sensitivity to better than 1fF for measuring very small changes in the capacitance of small devices, and 20,000-count resolution.

The Model 590 is available as a 1MHz unit (Model 590/1M), a 100kHz unit (Model 590/100k), or as a dual-frequency unit (Model 590/100k/1M). The Model 590/100k/1M is particularly useful for comparing industry-standard 1MHz data with more precise 100kHz data. The other models are useful in dedicated applications where only one frequency will be used.

A Test Voltage Meant for Semiconductors. The 590's test voltage is only 15mV rms, so small that negligible errors are introduced due to operating-point excursions. With larger voltages, the effect is to average capacitance over the span of voltage excursion, creating a CV curve with less definition.

C, G, and V in Any Format You Want. The Model 590 uses a classic quadrature phase-sensitive-detector circuit in combination with a precision digitally-generated drive circuit to gain independence of the capacitance and conductance measurements. On 100kHz models, ranges are from 2pF to 2nF with 20,000-count resolution. The extended range adapter (Model 5904) increases 100kHz capability to a 20nF range for measuring very large test devices or devices with a high dielectric constant. 1MHz models have 20,000-count ranges from 20pF to 2nF.

The internal bias source can supply up to 50mA from −20V to +20V with 5mV resolution. Up to 200V may be applied and monitored using an external source.

The following waveforms may be selected from the front panel or via bus commands:

DC: For measuring C and G at a fixed bias voltage over time.

STAIR: A + or − staircase for making C vs. V and G vs. V plots. **Figure 1** shows an example, indicating programmable parameters.

DUAL STAIR: To investigate hysteresis effects.

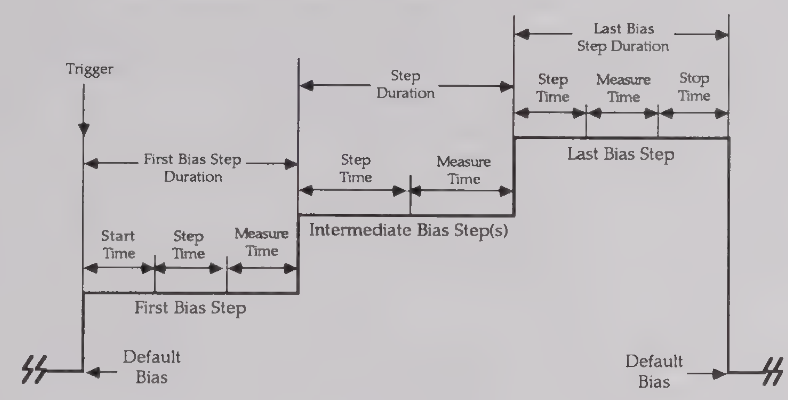
PULSE: For making deep depletion CV curves. Each pulse is incremented by the selected step voltage. Between pulses, the voltage stays at the default voltage.

EXT: For external voltage source when more than ±20V bias is desired. Rear panel BNC trigger connectors may be used to coordinate timing with external sources such as the Keithley Model 230, which also has BNC trigger connectors.

Make Measurements Fast. When making capacitance measurements, the Model 590 saves data in its internal buffers at rates up to 1024μs per point, in the C-t mode. 2000-count readings of C, G, and V may be obtained at rates up to 75 rdg/second in convenient ASCII format. 20,000-count ASCII readings at rates up to 18 rdg./second may be obtained using the IEEE-488 bus. The choices let you decide in each case how to trade off speed, resolution, and number of data points per CV curve.

You can define your own syntax using the TRANSLATOR capability. For example, one command on the IEEE-488 bus, such as "CV1", can replace a series of commands with parameter settings.

FIGURE 1: Bias Waveform For "Stair" Waveform



NOTES:
1. Start Time, Step Time, and Stop Time are programmable.
2. Measure Time is approximately 1/R, where R is the programmed reading rate.

Correct for 1MHz Connection Errors Easily. Unlike other CV instruments, the Model 590 offers you 3 ways to correct for 1MHz connection errors, in addition to subtraction of background capacitance:

1. Measure the impedance of the cable as a "driving point" impedance. This is an improvement over the correction for background capacitance only, but works only with cables.
2. Measure the connection path with a network analyzer, then enter transmission constants into the Model 590. It will calculate the appropriate correction factors. This is convenient if transmission constants are needed for other purposes.
3. Connect a known capacitance source at the DUT end of the cable or switching matrix. Enter the value of this source into the Model 590, which will adjust the display and the bus readings to the exact value of the source. This is the most accurate way of correcting for errors in the connection system because it corrects for all errors without involving any assumption other than linearity of the 2-port connection system. By using the Model 5907 Calibration Capacitors, total errors can be reduced to less than 0.5%, even with up to 15 meters of connecting cable or a switch matrix in the connection path. No other capacitance meter (or even systems costing many times more than the Model 590) has so extensive a selection of connection correction alternatives.

FIGURE 2: Model 590 Connection Correction Methods

Method	Decsription	Typical Accuracy	Comments
1	Driving point (front panel or bus)	2%	Cables only
2	Transmission line parameters (bus only)	1.5%	Can be used with complex paths
3	Calibration capacitor (bus only)	0.5%	Can be used with complex paths

Picture Perfect Plots. The internal plotter driver provides a camera-ready CV plot (or a plot of any of the analyses in **Figure 4**) to any digital plotter with HPGL® commands. The example in **Figure 3** shows the complete labelling of the axes, and notation of key control settings as provided. Normally, the C and V axes are scaled to accommodate the stored data. However, you can set the C and V axes to narrower ranges to provide a zoom capability, or always use the same scaling to intercompare many CV plots. No controller is needed—the Model 590 does it all.

FIGURE 3: Actual Model 590 Plot

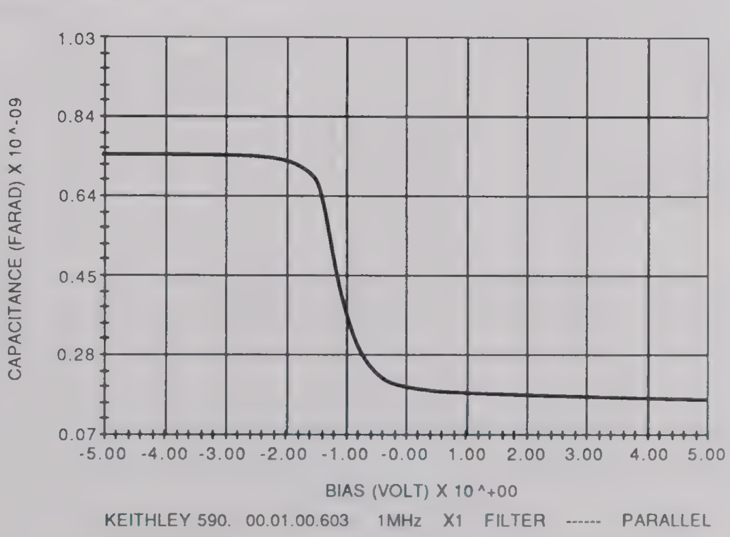
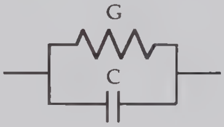
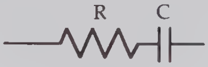


FIGURE 4: Model 590 Analysis Functions

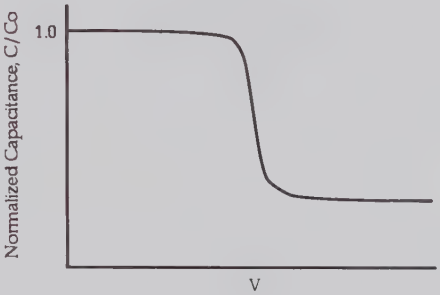
PARALLEL C and G vs. V: This calculation simply outputs the measured values of C, G, and V, corrected in accordance with the selected connection method (see **Figure 2**). This is the most fundamental data, since the circuit directly measures C and G at each V.



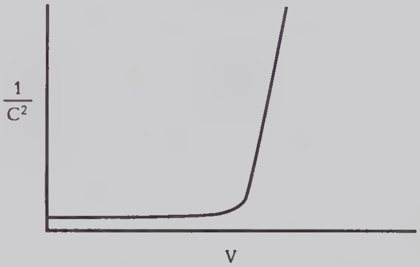
SERIES C and R vs. V: This outputs values for a series-equivalent model, calculated from the parallel-model C and G data at each V.



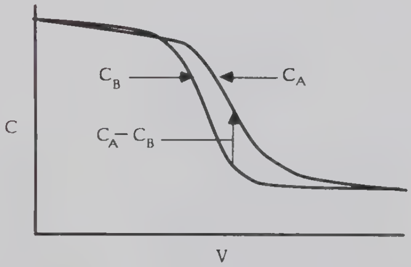
C/C_O and C_{MAX}: The C_{MAX} button or command searches BUFFER B for the maximum value, puts it into the C_O register, displays it on the display, and makes it available on the bus. This is often taken as the C_{OX}, the oxide capacitance, in a CV plot. Using C/C_O, the Model 590 will calculate the ratio of each C value to C_O. This has the effect of normalizing the CV curve to C_O, so that curves of devices with different oxide capacitance values may be easily compared. Other values may be entered for C_O if desired.



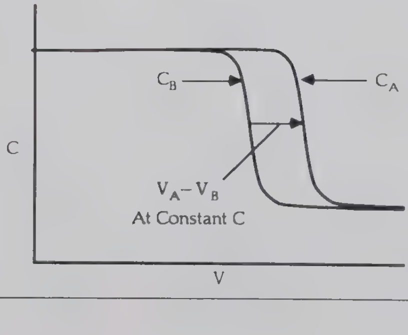
$1/C^2$: Many ideal CV curves exhibit an inverse parabolic relationship in certain regions. If this is the relationship, a plot of $1/C^2$ vs. V will be a straight line in the regions where the relationship holds. So this analysis provides an easy check on the quality of the data, since deviations from a straight line on a plot of $1/C^2$ vs. V are much more obvious than deviations from an inverse parabolic relationship on a C vs. V plot.



$C_A - C_B$: This is a particularly useful analysis when comparing CV curves on two devices, or two curves under different situations on the same device. A CV curve is taken on device B and stored in BUFFER B. Then a CV curve is taken on device A and stored in BUFFER A. The Model 590's output is $C_A - C_B$ at each V.



$V_A - V_B$ at constant C: This analysis allows you to directly examine shift in threshold (or other) voltage between two CV plots, and is particularly useful in oxide studies such as mobile ion tests. The Model 590 stores the first set of CV readings, then at each value of C in BUFFER A, calculates the value of V from C values in BUFFER B by interpolation. The output is thus $V_A - V_B$ at C_A. This provides an obvious indication of any shift in voltage between the two curves.



590/100k and 590/100k/1M FRONT PANEL SPECIFICATIONS

(4½ Digits)

RANGE	RESOLUTION	ACCURACY (1 Year)[2] 18°-28°C ±(%rdg + counts)	P-P NOISE[5] FILTER ON	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C	SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts)
2 pF	0.1 fF	0.12% + (500 × G/G_{FS} + 200)	6 fF	0.02% + (20 × G/G_{FS})	0.1 % + (3 × G/G_{FS})
2 μS	0.1 nS	0.12% + (50 × C/C_{FS} + 200)	4 nS	0.02% + (7 × C/C_{FS})	0.1 % + (3 × C/C_{FS})
20 pF	1 fF	0.12% + (260 × G/G_{FS} + 10)	6 fF	0.02% + (20 × G/G_{FS})	0.1 % + (3 × G/G_{FS})
20 μS	1 nS	0.12% + (22 × C/C_{FS} + 10)	4 nS	0.02% + (7 × C/C_{FS})	0.1 % + (3 × C/C_{FS})
200 pF	10 fF	0.12% + (260 × G/G_{FS} + 5)	90 fF	0.02% + (20 × G/G_{FS})	0.1 % + (3 × G/G_{FS})
200 μS	10 nS	0.12% + (22 × C/C_{FS} + 5)	60 nS	0.02% + (7 × C/C_{FS})	0.1 % + (7 × C/C_{FS})
2 nF	100 fF	0.12% + (260 × G/G_{FS} + 5)	900 fF	0.02% + (20 × G/G_{FS})	0.02% + (2 × G/G_{FS})
2 mS	100 nS	0.12% + (22 × C/C_{FS} + 5)	0.6 μS	0.02% + (7 × C/C_{FS})	0.02% + (3 × C/C_{FS})
20 nF*	1 pF	0.25% + (260 × G/G_{FS} + 5)[3]	9 fF	0.1 % + (30 × G/G_{FS})	0.02% + (2 × G/G_{FS})
20 mS	1 μS	0.25% + (22 × C/C_{FS} + 5)	6 μS	0.1 % + (10 × C/C_{FS})	0.02% + (2 × C/C_{FS})

Accuracy is maximum limit for $Q \geq 20$; typical for $Q < 20$.
*Using Model 5904 20nF/20mS Input Adapter.

590/1M and 590/100k/1M FRONT PANEL SPECIFICATIONS

(4½ Digits)

RANGE	RESOLUTION	ACCURACY (1 Year)[2] 18°-28°C ±(%rdg + counts)	P-P NOISE[5] FILTER ON	TEMPERATURE COEFFICIENT 0°-18°C & 28°-50°C ±(%rdg + counts)/°C	SHUNT CAPACITANCE LOADING EFFECT[4] ±(%rdg + counts)
20 pF	1 fF	0.29% + (300 × G/G_{FS} + 10)	6 fF	0.02% + (20 × G/G_{FS})	0.5 % + (25 × G/G_{FS})
200 μS	10 nS	0.29% + (120 × C/C_{FS} + 10)	40 nS	0.02% + (8 × C/C_{FS})	0.5 % + (10 × C/C_{FS})
200 pF	10 fF	0.29% + (300 × G/G_{FS} + 5)	100 fF	0.02% + (20 × G/G_{FS})	0.35% + (40 × G/G_{FS})
2 mS	100 nS	0.29% + (120 × C/C_{FS} + 5)	700 nS	0.02% + (8 × C/C_{FS})	0.35% + (16 × C/C_{FS})
2 nF	100 fF	0.29% + (300 × G/G_{FS} + 5)	200 fF	0.02% + (20 × G/G_{FS})	0.35% + (40 × G/G_{FS})
20 mS	1 μS	0.29% + (120 × C/C_{FS} + 5)	1 μS	0.02% + (8 × C/C_{FS})	0.35% + (16 × C/C_{FS})

Accuracy is maximum limit for $Q \geq 20$; typical for $Q < 20$.

NOTES:

1. G = conductance reading; C = capacitance reading; G_{FS} = full scale conductance; C_{FS} = full scale capacitance. Range and accuracy designations based on parallel RC model.
2. Front panel accuracy is relative to calibration source accuracy. Add front panel accuracy and source accuracy for total accuracy. Factory calibration source accuracy is 0.06% for 100kHz and 0.08% for 1MHz. CAL is to be used to cancel initial zero, gain, and phase error terms within 8 hours of measurement or whenever ambient temperature changes by more than 2°C.
3. The 5904 must be calibrated with a particular 590/100k to achieve specified accuracy.
4. "Shunt Capacitance Loading" is additional accuracy with equal shunt load on Output and Input, per 100pF shunt load.
5. Noise specified with 500pF shunt loading on Output and Input. Noise on 2pF and 20pF ranges is typical with 100pF shunt load; 500pF will increase noise no more than ×2. Measured at 10 rdg/s rate.

CAPACITANCE NON-LINEARITY: <0.1% of range, for $Q > 20$ or $D < 0.05$, 18°-28°C.

TEST VOLTAGE: 15mV rms ±10%.

TEST FREQUENCY: 590/100k: 100kHz. **590/1M:** 1MHz. Tolerance: ±0.1%.

BIAS SOURCE

INTERNAL BIAS SOURCE OUTPUT: −20.000V to +20.000V in 5mV steps.

ACCURACY (1 Year, 18°-28°C): ±(0.05% setting + 10mV) exclusive of loading errors.

DC OUTPUT RESISTANCE: 5Ω maximum.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.005% + 1mV)/°C.

MAXIMUM OUTPUT CURRENT: ±50mA.

SETTLING TIME: <1ms to 1% of final value.

NOISE: Typically <200μV p-p, 0.1Hz-1MHz; 3mV p-p to 75MHz.

BIAS WAVEFORM:

DC: Outputs the programmed value.

STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V.

DUAL STAIR: Output changes in increments of BIAS STEP V from FIRST BIAS V to LAST BIAS V, then back to FIRST BIAS V.

PULSE: Outputs pulse train; amplitude increments by BIAS STEP V from FIRST BIAS V to LAST BIAS V (each pulse is from DEFAULT BIAS V to FIRST BIAS V for duration of STEP TIME, then back to DEFAULT BIAS V). Also programmable for single pulse.

EXT: Allows application of external bias source (via VOLTAGE BIAS INPUT).

BIAS PARAMETERS: FIRST BIAS V, LAST BIAS V, DEFAULT BIAS V, BIAS STEP V, START TIME, STOP TIME, STEP TIME, COUNT.

BIAS STEP V: Programmable in 5mV steps to 20V. Polarity selectable + or −.

START TIME: After transition from DEFAULT BIAS V to FIRST BIAS V, START TIME must elapse before first measurement. Programmable in increments of 1024μs from 1 to 65,536 increments.
Accuracy: ±(0.1% + 1ms).

STEP TIME: The period between the transition of BIAS STEP V and the start of the next measurement. Programmable in increments of 1024μs from 1 to 65,536 increments. **Accuracy:** ±(0.1% + 1ms).

STOP TIME: The period between the end of the final measurement and the transition from LAST BIAS V to DEFAULT BIAS V. Programmable in increments of 1024μs from 1 to 65,536 increments.
Accuracy: ±(0.1% + 1ms).

EXTERNAL VOLTAGE BIAS INPUT: Rear panel input terminals allow application of external bias source up to ±200V, ±50mA.
Input Impedance: 100kΩ paralleled by 1μF.

VOLTAGE BIAS MONITOR: Rear panel output terminals allow monitor of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. **Level:** 1V = 1V out. **Output Resistance:** 1kΩ.

VOLTAGE BIAS DISPLAY: Front panel 4½-digit display allows direct readback of the DC BIAS SOURCE output or externally applied VOLTAGE BIAS INPUT. **Accuracy:** ±(0.05% + 5 counts). **Temperature Coefficient:** ±(0.005% + 0.1 count)/°C.

590/CV Analyzer

100kHz and 1MHz C vs. V, G vs. V, or C vs. t Curves

ANALYSIS CAPABILITY

(Programming and output available from front panel or IEEE-488 bus)

READING BUFFERS A and B: Two data buffers allow storage and mathematical manipulation on up to 450 measurement triplets: capacitance, conductance, and voltage. In C vs. t, capacitance and index only are stored (up to 1350 points).

$1/C^2$: Performs the inverse of C^2 on the capacitance data stored in reading buffer.

C/C_O: Allows normalization of capacitance readings stored in reading buffer to a user-programmable reference value C_O.

C_{MAX}: Searches reading buffer for the maximum capacitance value.

$C_A - C_B$: Sequentially computes the difference between corresponding capacitance readings stored in reading buffer A and reading buffer B.

$|V_A - V_B|$: Calculates the corresponding difference in applied voltage for values of capacitance in reading buffer B equal to each value in reading buffer A.

C vs. t: Allows fast measurement of capacitance vs. time (1000 rdg/s).

CABLE COMPENSATION

(Up to 8 setups can be stored in non-volatile memory)

CALIBRATION CAPACITOR COMPENSATION: Corrects for errors due to cables or switching matrix up to 5 meters effective (electrical equivalent) length. Two measurements are made with cables and matrix terminated with precision reference capacitors in place of the DUT. Model 5907 Cable/Matrix Calibration Capacitor Set required. Bus programmable only. 1MHz only. **Accuracy:** ±(0.5% + applicable front panel specification), typical.

SINGLE-ENDED CABLE and S-PARAMETER COMPENSATION can also be made. See manual for detailed information.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, E1, C0 (for stand alone plotting C28 is used).

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Filter, Frequency, Bias Waveform, Bias Parameters, Plotting, Plotter Parameters, EOI, Trigger, Terminator, 450 Data Point Storage, Calibration, Cable Correction, Display, Status, Service Request, Self Test, Output Format.

TRANSLATOR: Up to 250 bytes of definitions allow variable passing, definition decomposition and listing.

GENERAL

DISPLAY: Three 4½-digit displays for capacitance, conductance, and voltage bias.

RANGE: Manual or autoranging (for rates up to 18 rdg/s); 10% overrange allowable.

OVERRANGE INDICATION: Display reads OFLO.

AVAILABLE MEASUREMENT RATES (to internal buffer): **4½-Digit:** 1, 10, and 18 rdg/s. **3½-Digit:** 75 and 1000 rdg/s.

FILTER: 1-pole analog; pole at 37Hz. Filters both capacitance and conductance signals. For FILTER off, multiply p-p noise specification by 5.

CAL: Initiates self-calibration to internal reference capacitor. Used to cancel initial zero, gain, and phase errors.

ZERO: Allows zeroing of on range readings. Allows relative readings to be made with respect to a baseline value.

MAXIMUM OVERLOAD: OUTPUT, Voltage Bias Input: 200V internally fused at ⅛A. INPUT: Clamped by diodes to ±0.7V. Maximum current 200mA. Analog Outputs: 15V.

MAXIMUM COMMON MODE VOLTAGE (INPUT and OUTPUT, Voltage Bias Input): 30V rms, dc to 60Hz. Rear panel switch allows connection of INPUT low to chassis.

ANALOG OUTPUTS (Capacitance and Conductance): Level: 2V output at full range. **Initial Offset:** ±25mV. **Output Resistance:** 1kΩ. **Response Time:** 1ms to 1% of final value with filter off; 25ms maximum with filter on.

PLOTTER: Digital plotter output controls HP7470A plotter or equivalent using HPGL via IEEE-488 for real-time plotting of all measurements as well as results of math computations, with grids and labels. Talks to plotter on address 05. HPGL commands used are IN, IP, IW, PA, PD, PU, SC, SI, SP.

FRONT PANEL SETUPS: Up to 7 front panel setups can be stored in non-volatile memory.

EXTERNAL TRIGGER: TTL compatible External Trigger Input and Output.

INPUT CONNECTORS: Isolated BNC for INPUT and Voltage Bias Input.

OUTPUT CONNECTORS: Isolated BNCs for OUTPUT, Voltage Bias Monitor, Analog Outputs, and External Trigger.

ENVIRONMENT: Operating: 0°-50°C, relative humidity 70% non-condensing up to 35°C. **Storage:** −25° to +65°C.

WARMUP: 1 hour to rated accuracy.

COOLING: Internal fan and filter for forced air cooling.

POWER: 105-125V or 210-250V (external switch selected), 50Hz to 60Hz, 100VA maximum. 90-110V and 180-220V version available upon request.

DIMENSIONS, WEIGHT: 133mm high × 435mm wide × 448mm deep (5¼ in. × 17⅛ in. × 17 9/32 in.). Net weight 9.1kg (20 lbs.).

ACCESSORIES SUPPLIED: Two Model 7051-5 BNC cables.

ACCESSORIES AVAILABLE:

Model 2288:	Fixed Rack Mounting Kit
Model 2289A:	Slide Rack Mounting Kit
Model 5904:	20nF/20mS Adapter
Model 5905:	Calibration Sources and Adapters for 590/1M
Model 5906:	Calibration Sources and Adapters for 590 1/M, 590/100k, 590/100k/1M, and 5904
Model 5907:	Cable/Matrix Calibration Sources
Model 7007-1:	Shielded IEEE-488 Digital Cable, 1m (3.3 ft.)
Model 7007-2:	Shielded IEEE-488 Digital Cable, 2m (6.6 ft.)
Model 7051-2:	BNC to BNC Cable, 0.8m (2 ft.)
Model 7051-5:	BNC to BNC Cable, 1.5m (5 ft.)
Model 7051-10:	BNC to BNC Cable, 3m (10 ft.)

See page 85 for descriptions of all accessories.

Quasistatic CV Meter/595

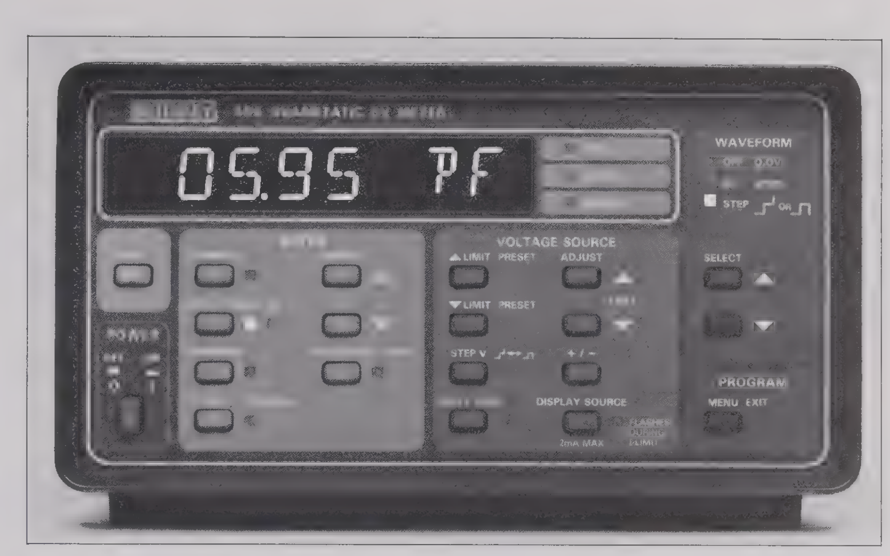
Quasistatic CV, IV, and fA Current

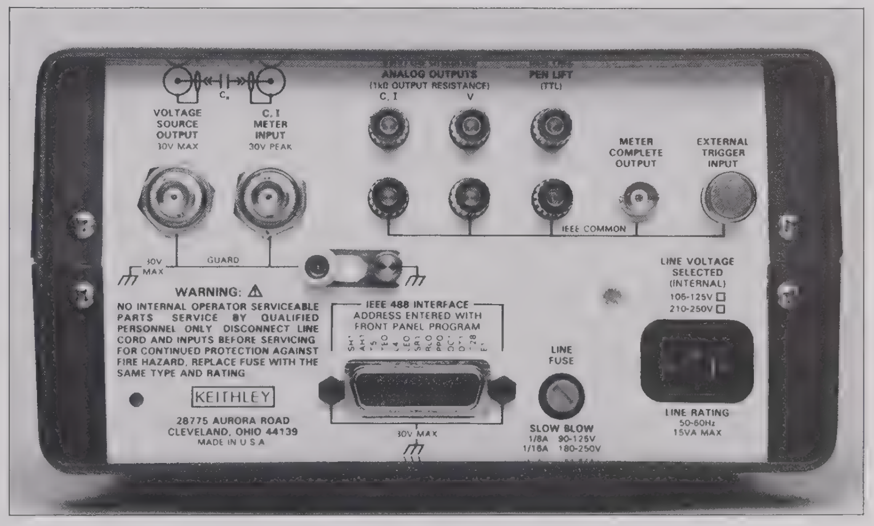
Uses a new feedback charge technique:

- **Distinguishes resistive and leakage currents from capacitive displacement currents**
- **Corrects capacitance readings for background leakage current**
- **Output signal magnitude is independent of measurement rate**
- **Rapid assurance of device equilibrium**

Other Model 595 features:

- **Measures capacitance from 10fF change to 20nF**
- **Measures current from 1fA change to 200μA.**
- **Built-in IEEE-488 bus and plotter driver with grid & labeling**
- **Plots CV, IV, Q/t**


05.95 PF
WAVEFORM
STEP
VOLTAGE SOURCE
LIMIT
PRESET
ADJUST
LIMIT
PRESET
STEP V
+/−
DISPLAY SOURCE
2mA MAX
SELECT
PROGRAM
MENU EXIT
POWER


VOLTAGE SOURCE OUTPUT 30V MAX
C, I METER INPUT 30V PEAK
ANALOG OUTPUTS (1kΩ OUTPUT RESISTANCE)
C, I
V
PEN LIFT (TTL)
METER COMPLETE OUTPUT
EXTERNAL TRIGGER INPUT
IEEE COMMON
30V MAX
GUARD
WARNING:
NO INTERNAL OPERATOR SERVICEABLE PARTS SERVICE BY QUALIFIED PERSONNEL ONLY DISCONNECT LINE CORD AND INPUTS BEFORE SERVICING FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH THE SAME TYPE AND RATING
KEITHLEY
28775 AURORA ROAD CLEVELAND, OHIO 44139 MADE IN U.S.A.
IEEE 488 INTERFACE ADDRESS ENTERED WITH FRONT PANEL PROGRAM
LINE FUSE
SLOW BLOW
1/8A 90-125V
1/16A 180-250V
LINE VOLTAGE SELECTED (INTERNAL)
105-125V
210-250V
LINE RATING 50-60Hz 15VA MAX

Rear panel of Model 595 has all connections to the device under test as well as analog outputs, pen lift, triggers, and IEEE-488 bus connector.

The Keithley 595 uses a new technique for the measurement of quasistatic capacitance versus voltage characteristics of semiconductor devices. It also directly measures dc currents to 1fA. This allows you to rapidly measure IV or quasistatic CV characteristics of many semiconductor materials and components. The 595 can also be used to directly measure current or quasistatic capacitance at a single operating point.

This new "feedback charge" quasistatic CV measurement technique offers higher signal-to-noise ratio at the frequencies of interest. The signal is independent of measurement time, and is easily distinguished from error currents.

The Feedback Charge Method

In the circuit of **Figure 1**, one terminal of the DUT (C_X, the capacitance to be measured) is connected to a voltage source which is part of the Model 595. The other is connected to the input of an internal feedback charge amplifier (integrator). This input is a virtual ground, so the bias voltage across the DUT is essentially equal to the output of the voltage source.

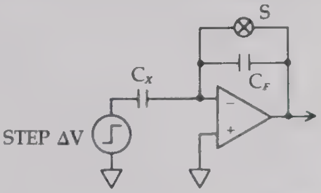
Initially, the feedback capacitor of the integrator is discharged by closing a low leakage switch (S) in parallel with it. When the measurement is ready to begin, S is opened. Any charge transferred to the input of the integrator will now cause a change in the integrator output:

$$\Delta V_{OUT} = -\Delta Q/C_F$$

The voltage source, which is connected to the substrate, is then incremented by a small amount, ΔV. When the voltage is incremented, a charge will be transferred to C_X which is proportional to the voltage increment ($\Delta Q = C_X \Delta V$). The charge will be transferred into the integrator and will cause a voltage change at its output. By measuring the integrator output before and after the voltage source step ΔV, ΔQ is determined. The unknown capacitance is merely:

$$C_X = \Delta Q/\Delta V = -C_F \Delta V_{OUT}/\Delta V.$$

FIGURE 1: Feedback Charge Method


S
C_X
C_F
STEP ΔV
−
+

$$\Delta Q = C_X \Delta V; \ \Delta V_{OUT} = \frac{-\Delta Q}{C_F}$$

- Fixed gain for source noise
- Fixed signal/noise with increasing Δt
- Can distinguish signal charge from error currents

Figure 2 describes the way in which the charge waveform is measured in the Model 595. The waveform shown is that of an MOS capacitor in the presence of system leakage or a leaky oxide. The symbols Q_1, Q_2, and Q_3 represent three measurements of charge made at three specific times. Q_1 is the baseline charge immediately preceding the voltage step. Q_3 is measured after a specified DELAY TIME (t_{DELAY}) and is an indication of the final charge transferred through the DUT. Q_2 is measured before Q_3 (preceding it by t_O) and is useful in determining the slope of the charge waveform before the final charge measurement.

The simple definition of C_X,

$$C_X = (Q_3 - Q_1)/V_{STEP},$$

would be correct if there were no background current, such as that which causes the background slope during integration in **Figure 2**. The calculation for corrected C_X accounts for this background current and calculates the true capacitance by subtracting the charge contributed by the background current.

In the Model 595, the following parameters of the measurement may be selected from the front panel or via the IEEE-488 bus:

Staircase or square wave VOLTAGE OUTPUT

t_{DELAY} = 70ms to 200s in 10ms increments

$t_1 \approx$ 40ms

$t_{STEP} = t_{DELAY} + t_1$

$t_O = (t_{DELAY})/8$ or 44ms, whichever is greater

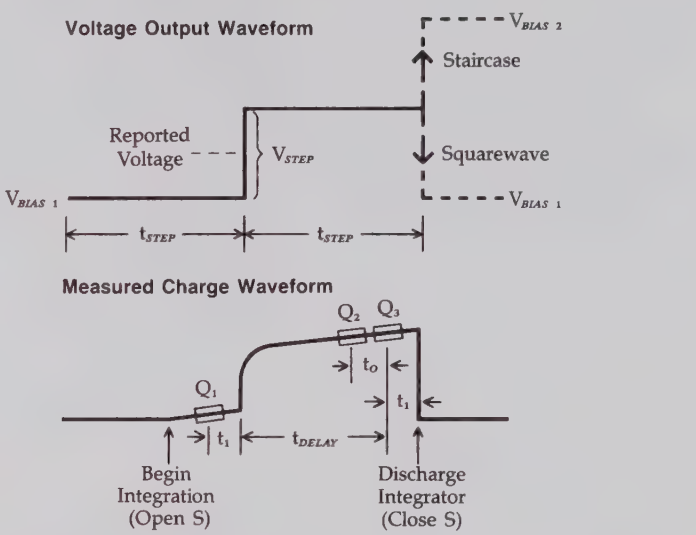
V_{STEP} = 10mV, 20mV, 50mV, or 100mV

V_{BIAS} = −20V to +20V in 10mV increments

Quasistatic CV Characteristics

Note that in **Figure 2**, the VOLTAGE OUTPUT waveform is selectable: a square wave or a staircase may be used. This allows you to measure quasistatic capacitance at a specific voltage (using a square wave) or over a range of voltages (using a staircase waveform).

FIGURE 2: Model 595 Timing, Voltage, and Charge Waveforms



$$C_X = \frac{Q_3 - Q_1}{V_{STEP}}$$

If $Q/t \rightarrow 0$

$$Q/t = \frac{Q_3 - Q_2}{t_O}$$

$$C_X \text{ (corrected)} = \frac{(Q/t)(t_{DELAY} + t_1)}{V_{STEP}}$$

$(Q/t \neq 0)$

Reported Voltage $V = V_{BIAS} + \frac{1}{2}V_{STEP}$

The fact that the Model 595 easily measures quasistatic capacitance at a single bias point can be used to significantly reduce total measurement time for a quasistatic CV curve. Instead of having to make many complete CV curves to determine equilibrium, which may take hours, various delay times may be tried at a fixed bias point in the inversion region. This reduces testing time to a few minutes.

Current Measurements

Not only is the Model 595 an excellent CV meter, it utilizes Keithley's well-known expertise to measure very low currents. Sensitivity is 1fA per count. Maximum input current is 5fA. This makes it useful for measuring even small gate currents or making sensitive IV curves.

Plotter Driver

You don't need to tie up a computer to make quasistatic CV, Q/t, or IV plots with the Model 595. It uses the IEEE-488 bus port to drive a plotter. Front panel controls permit you to plot a grid with specified HI and LO limits. No software, computers, or programs are needed. Just select the digital output you want (C, Q/t, or I vs. V), desired limits, and plot.

Measuring C/C_{OXIDE} vs. V

Using C/C_O, all readings may be displayed as a ratio to a stored value of C_O. Thus the value of C_{OXIDE} as measured in the accumulation region can be stored as C_O; then a curve of C/C_{OXIDE} vs. V can be displayed, presented on the IEEE-488 bus, or directly plotted using a digital or analog plotter.

CAPACITANCE (C)

RANGE	RESOLUTION	ACCURACY* (1 Year) 18°-28°C ±(%rdg+counts)	MAXIMUM ALLOWABLE Q/t AT HALF RANGE C DELAY TIME =0.07s STEP V = 0.10V
200 pF	10 fF	1.0 + 10	90.00 pA
2 nF	100 fF	0.8 + 2	0.900 nA
20 nF	1 pF	0.6 + 2	9.000 nA

*Exclusive of noise, for STEP V ≥0.05V and DELAY TIME ≤1 second. For other parameters, derate by (5mV/STEP V)×(DELAY TIME/1 second) in pF at 23°C. Double the derating for every 10°C rise in ambient temperature above 23°C.

TYPICAL PEAK-TO-PEAK NOISE (with supplied cables): ±(0.015% rdg + 0.006pF) × (100mV/STEP V) ± 1 count with FILTER 2, 0.1Hz to 10Hz.

Q/t: Measures non-equilibrium current and leakage current in the device under test during a capacitance measurement.

Display: 3 digits typical; resolution from 0.01fA to 0.01nA per count depending on range, STEP V, and DELAY TIME.

Measurement Time: DELAY TIME/8 or 0.044s, whichever is greater. Sampled at the end of each capacitance measurement.

Accuracy (1 Year, 18°-28°C): ±(1.0% rdg + 2 counts) exclusive of input bias current and noise.

C/C_o: Outputs normalized reading (up to 1.9999) as a ratio of the measured capacitance to a user-stored value of C_o.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-40°C): ±(0.02% rdg + 0.1 count)/°C.

CURRENT (I)

RANGE	RESOLUTION	ACCURACY* (1 Year) 18°-28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-40°C ±(%rdg+counts)/°C
20 pA	1 fA	1.5 + 14	0.15 + 3
200 pA	10 fA	1.5 + 2	0.15 + 0.3
2 nA	100 fA	0.25 + 6	0.015 + 3
20 nA	1 pA	0.25 + 1	0.015 + 0.3
200 nA	10 pA	0.1 + 4	0.01 + 3
2 μA	100 pA	0.1 + 1	0.01 + 0.3
20 μA	1 nA	0.1 + 4	0.01 + 3
200 μA	10 nA	0.1 + 1	0.01 + 0.3

*When properly zeroed.

NMRR: 70dB on pA ranges, 60dB on nA and μA ranges, at 50 or 60Hz ±0.1%.

VOLTAGE SOURCE (V)

OUTPUT: −20.00V to 20.00V in 0.01V increments.

ACCURACY (1 Year, 18°-28°C): ±(0.2% + 10mV).

TEMPERATURE COEFFICIENT (0°-18°C & 28°-40°C): ±(0.005% + 200μV)/°C.

MAXIMUM OUTPUT CURRENT: ±2mA; active current limit at <4mA with annunciation.

SETTLING TIME: <3ms to rated accuracy.

NOISE: <(1ppm of output voltage + 100μV) p-p from 0.1 to 10Hz.

STEP Voltage: Selectable as 0.01V, 0.02V, 0.05V, or 0.10V (±2%). Polarity selectable + or −.

DELAY TIME: 0.07s to 199.99s in 0.01s increments (±0.05%).

STEP TIME: DELAY TIME plus 0.04s typical.

WAVEFORM: OFF: Outputs 0.0V ±0.01V.
DC: Outputs the programmed voltage.
STEP: Outputs changes in increments of STEP V from programmed voltage in either staircase or squarewave.

SQUAREWAVE: Repeatedly toggles between the programmed voltage and the programmed voltage plus STEP V, dwelling at each level for Step Time.

STAIRCASE: Repeatedly increments the output by STEP V until the upper or lower LIMIT is reached, dwelling at each level for Step Time.

ANALOG OUTPUTS

C, I OUTPUT LEVEL: 1V=10,000 counts on ×1 gain; 1V=1000 counts on ×10 gain.

V OUTPUT LEVEL: 1V = 10V on voltage source output.

MAXIMUM OUTPUT VOLTAGE: ±2V.

OUTPUT RESISTANCE: 1kΩ.

ACCURACY: ±(0.25% of displayed reading + 2mV).

RESPONSE TIME: Follows display.

ISOLATION: 30V peak from chassis or GUARD to ANALOG OUTPUT LO, which is connected to IEEE COMMON.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C28, E1.

PROGRAMMABLE PARAMETERS: Function, RANGE, ZERO CHECK, CORRect, SUPPRESS, C/C_o, STORE C_o, Voltage Source Parameters, WAVEFORM, Display Parameter, Filter, Trigger, Analog Output ×10, PEN LIFT, Capacitance Correction, Calibration, Self Test, Output Format, SRQ, Status, ASCII Terminator, EOI.

PLOTTER: Controls HPGL® plotter (such as HP 7475A) via IEEE-488 for real time plotting of C, Q/t, or I vs. V curves. Accessed by selecting Model 595 address 42 or 43. Talks to plotter on address 05. HPGL commands used are IN, IP, IW, PA, PD, PU, SC, SI, SP.

GENERAL

DISPLAY: 4½-digit numeric LEDs with appropriate decimal point and polarity indication. Signed 2-digit alphanumeric exponent.

UPDATE RATE: In I, one reading each Step Time.
In C, one reading each 2× Step Time.

OVERRANGE INDICATION: Display reads OL.

INPUT BIAS CURRENT (all functions): <5fA (5×10^{-15}A) at 23°C after warmup. Approximately doubles for every 10°C increase in ambient temperature above 23°C.

INPUT VOLTAGE BURDEN: <1mV.

MEASUREMENT SETTLING TIME: Within one reading except 2.5s (to 1% of step change) on pA ranges.

PROGRAMS: Provide front panel access to Filter, Trigger, Analog Output ×10, Corrected Capacitance, IEEE-488 address, Alpha or Numeric Exponent, plotter Y Hi Limit, Y Lo Limit, Grid, 50/60Hz selection, and Digital Calibration.

SUPPRESS: Allows zeroing of on-range **C**, **C/C_o**, or **I** readings. Allows relative readings to be made with respect to a baseline value.

FILTER: Code	Readings Weighted	Typical White Noise Reduction	Typical Use
0	1	None	OFF
1	3	1.7	C or I vs. V measurements
2	9	2.5	C or I vs. V measurements
3	24	5	Steady C, I measurements

MAXIMUM INPUT: 30V peak, dc to 60Hz sine wave.

MAXIMUM COMMON MODE VOLTAGE: 30V maximum, dc to 60Hz sine wave.

INPUT CONNECTOR: Isolated BNC on rear panel.

OUTPUT CONNECTORS: Isolated BNCs on rear panel for VOLTAGE SOURCE OUTPUT, EXTERNAL TRIGGER, and METER COMPLETE. 5-way binding posts on rear panel for ANALOG OUTPUTs, PEN LIFT, GUARD, and Chassis.

EXTERNAL TRIGGER: TTL compatible EXTERNAL TRIGGER and METER COMPLETE.

ENVIRONMENT: Operating: 0° to 40°C, relative humidity 70% non-condensing up to 35°C. **Storage:** −25° to +65°C.

WARMUP: 2 hours to rated accuracy.

POWER: 105-125V or 210-250V (internal switch selected), 50Hz to 60Hz, 15VA max. 90-110V and 180-220V version available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.2kg (6 lbs., 14 oz.).

ACCESSORY SUPPLIED: Two Model 4801 Low Noise BNC Input Cables.

ACCESSORIES AVAILABLE:

Model 1019A-1:	5¼-in. Single Fixed Rack Mounting Kit
Model 1019A-2:	5¼-in. Dual Fixed Rack Mounting Kit
Model 1019S-1:	5¼-in. Single Slide Rack Mounting Kit
Model 1019S-2:	5¼-in. Dual Slide Rack Mounting Kit
Model 4801:	Low Noise Input Cable, 1.2m (4 ft.), BNC to BNC
Model 4803:	Low Noise Cable Kit
Model 5955:	Calibration Sources
Model 6104:	Test Shield
Model 7007-1:	Shielded IEEE-488 Digital Cable, 1m (3.3 ft.)
Model 7007-2:	Shielded IEEE-488 Digital Cable, 2m (6.6 ft.)

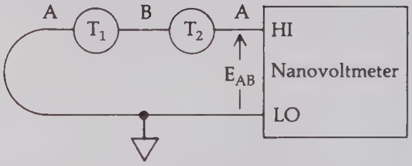
See page 85 for descriptions of all accessories.

Significant errors may be introduced in low voltage measurements by noise and drift sources which can be ignored at higher levels. These sources include Johnson noise, thermal EMFs, magnetic fields, and ground loops. Taking steps to understand and minimize these factors is crucial for making meaningful measurements at low voltage.

Thermal EMFs

Thermoelectric voltages are the most common source of errors in low-voltage measurements. These voltages arise when junctions of dissimilar materials are at different temperatures, as in **Figure 1**. Values for the thermoelectric power (Q_{AB}) of various materials with respect to copper are shown in **Table 1.**

FIGURE 1: Thermal EMFs



The thermal EMF developed by dissimilar metals A and B in a series circuit is:

$$E_{AB} = Q_{AB}\,(T_1 - T_2)$$

T_2 — Temperature of the A to B junction in °C

T_1 — Temperature of the B to A junction in °C

Q_{AB} — Thermoelectric voltage coefficient of material A with respect to B, μV/°C

TABLE 1: Thermoelectric Potentials

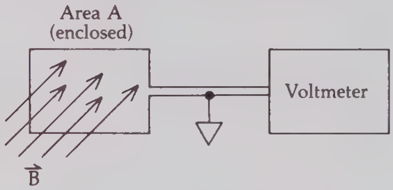
Materials	Thermoelectric Potential
Cu - Cu	≤0.2μV/°C
Cu - Ag	0.3μV/°C
Cu - Au	0.3μV/°C
Cu - Cd/Sn Solder	0.3μV/°C
Cu - Pb/Sn Solder	1 - 3μV/°C
Cu - Si	400μV/°C
Cu - Kovar	40μV/°C
Cu - Cu Oxide	1000μV/°C

Constructing circuits using the same material for conductors minimizes the thermal EMF. For example, gold or silver has a lower thermal EMF than lead-tin solder by a factor of ten. And connections made by crimping copper sleeves and lugs result in cold-welded copper-to-copper junctions which generate even less thermal EMF.

Minimizing temperature gradients within the circuit also reduces thermal EMF. A technique for accomplishing this is to place all junctions in close proximity and provide good thermal coupling to a common massive heat sink. This coupling must take place through electrical insulators having high thermal conductivity. Since most electrical insulators do not conduct heat well, special insulators such as hard anodized aluminum, beryllium oxide, specially filled epoxy resins, sapphire, or diamond must be used to thermally couple junctions to the heat sink.

In addition, allowing test equipment to warm up and reach thermal equilibrium in a constant ambient temperature also minimizes thermal EMF effects. Any remaining thermal EMF which is relatively constant can be compensated by zero controls provided on the measuring instrument. To keep ambient temperatures constant, equipment should be kept away from direct sunlight, exhaust fans, and similar sources of hot or cold air. Wrapping connections in insulating foam (e.g., polyurethane) also minimizes ambient temperature fluctuation due to air movement.

FIGURE 2: Low Voltages Generated by Magnetic Fields



The voltage developed due to a field passing through a circuit enclosing a prescribed area is:

$$E_B = \int_A \frac{\partial \vec{B}}{\partial t}\, dA$$

$\vec{B}$ = Magnetic field intensity

$\frac{\partial \vec{B}}{\partial}$ = Rate of change of $\vec{B}$ with time

Integral is to be evaluated over the area enclosed by the circuit

Magnetic Fields

The motion of circuit leads in magnetic fields generates spurious voltages. Even the earth's relatively weak magnetic field can generate nanovolts in dangling leads, so leads must be kept short and rigidly tied down.

Basic physics shows that the amount of voltage a magnetic field induces in a circuit is proportional to the area the circuit leads enclose, as shown in **Figure 2**. Thus, leads must be run close together and/or magnetically shielded to minimize induced magnetic voltages. One commonly-used magnetic shielding material is mu-metal, a special alloy with high permeability at low magnetic flux densities. **Figure 3** shows two ways of

FIGURE 3: Minimizing Interference from Magnetic Loops

Figure 3a: Large Magnetic Loop

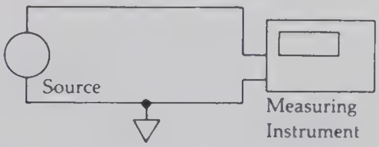
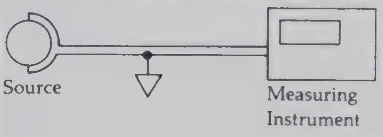


Figure 3b: Minimized Magnetic Loop



locating the leads from the source to the voltmeter: In **Figure 3a**, a large area is enclosed (thus a large voltage is developed); in **Figure 3b**, much less area is enclosed, thus minimum voltage is developed.

Conductors which carry large currents should also be shielded or run as twisted pairs to prevent generating magnetic fields that affect other circuits.

In addition to these techniques, ac signals from magnetic fields can be filtered at the input of the instrument, and the instrument can be physically moved further from the source of a (high) magnetic field.

Ground Loops

Noise and error voltages also arise from so-called ground loops. When the source and the measuring instrument are both connected to a common ground bus, a loop is formed as shown in **Figure 4a**. A voltage V_G between the source and instrument grounds will cause a current (I) to flow around the loop. This current will create an unwanted voltage in series with the source voltage. From Ohm's Law:

$$E = IR$$

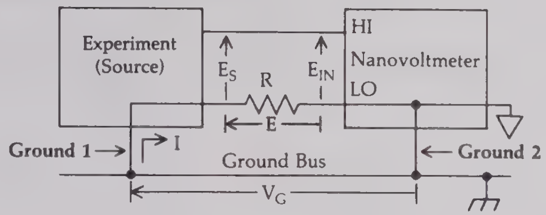
where E = ground loop interfering voltage; R = the resistance in the signal path through which the ground loop current flows; and I = the ground loop current.

A typical example is a number of instruments plugged into power strips on different instrument racks. Frequently, there is a small difference in potential among the ground points. This potential difference can cause large currents to circulate and create unexpected voltage drops.

The cure for ground loops is to ground all equipment at one point. The easiest way of accomplishing this is to use isolated power sources and instruments, then find a single good earth-ground point for the entire system, as shown in **Figure 4b**.

FIGURE 4: Unwanted Voltages Generated by Ground Loops

Figure 4a: Multiple Grounds (Ground Loops)



Input voltage to the nanovoltmeter is:

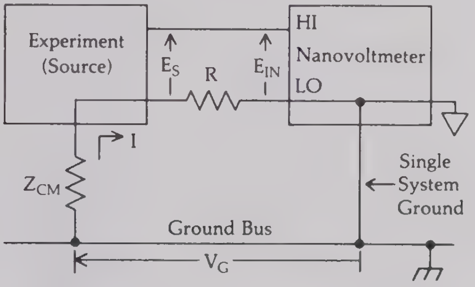
$E_{IN} = E_S + I\,R$

- Resistance of input LO connection (typically around 100mΩ)
- Current passing through input LO connection due to ground voltages (V_G) in the ground bus (magnitude may be amperes)
- Source voltage (desired signal)

I R may exceed E_S by orders of magnitude.

$E_{IN} \approx I\,R$

Figure 4b: Single System Ground



Input voltage to the nanovoltmeter is:

$E_{IN} = E_S + I\,R$

- Resistance of input LO connection (typically around 100mΩ)
- Current passing through Z_{CM} (MΩ or GΩ) due to V_G and currents in the source (magnitude is typically nA's)
- Source voltage (desired signal)

$E_{IN} \approx E_S$, since I R is now insignificant compared to E_S.

Johnson Noise

The fundamental limit to measurement is Johnson noise in the source resistance. In any resistance, thermal energy produces motion of charged particles. This charge movement results in noise which is often called Johnson or thermal noise. The power available from this motion is given by:

$$P = 4kT\Delta f$$

where:

k = Boltzmann's Constant (1.38×10^{-23}J/°K)

T = temperature in °K

Δf = noise bandwidth in Hz.

Johnson voltage noise developed in a resistor R is:

$$E = \sqrt{4kTR\Delta f} \text{ volts, rms}$$

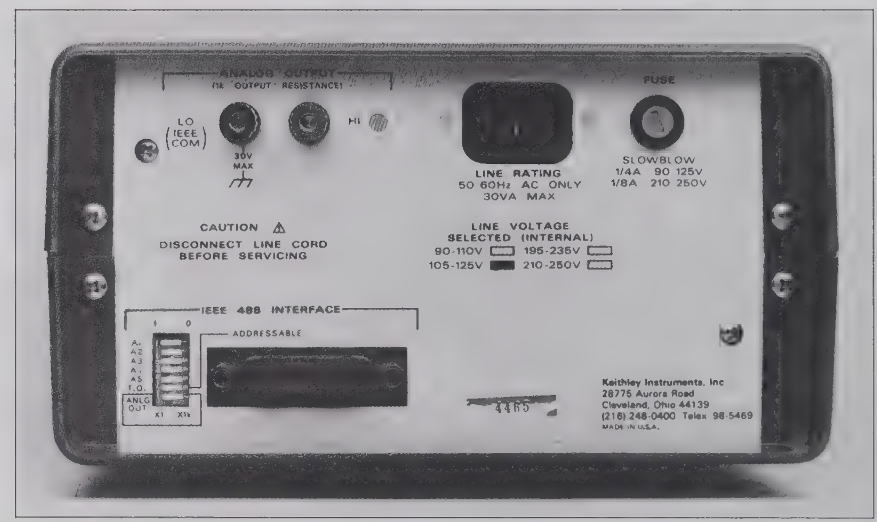
At room temperature (300°K), the above equation becomes:

$$E_{p\text{-}p} = 6.5 \times 10^{-10}\sqrt{R\Delta f}$$

181/Nanovoltmeter

System/Bench

1.8 10000
1000V
POWER
FILTER
DAMPING
mV INPUT


ANALOG OUTPUT
(1k OUTPUT RESISTANCE)
LO
(IEEE COM)
HI
30V MAX
FUSE
LINE RATING
50 60Hz AC ONLY
30VA MAX
SLOWBLOW
1/4A 90 125V
1/8A 210 250V
CAUTION
DISCONNECT LINE CORD
BEFORE SERVICING
LINE VOLTAGE
SELECTED (INTERNAL)
90-110V
195-235V
105-125V
210-250V
IEEE 488 INTERFACE
ADDRESSABLE
ANLG OUT
X1
X1k
Keithley Instruments, Inc
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400 Telex 98-5469
MADE IN U.S.A.

- **10nV sensitivity**
- **10nV/°C stability**
- **Analog output**
- **6½-digit resolution**
- **Fully programmable**
- **Standard IEEE-488 interface**
- **Pushbutton zero**

The 181 was designed to provide usable 10nV sensitivity. A proprietary JFET input amplifier provides the ultra-low noise and high linearity required for this application.

The 181 should not be confused with μP DMMs that average microvolt readings, then display "nanovolts". The 181 is *optimized* for nanovolt measurements. Thus, as opposed to DMMs, which average many readings to obtain resolution below 1μV, the 181 makes measurements down to 10nV with only 30nV noise in a single conversion.

Stability. The 181's zero stability is typically 10nV/°C for ambient temperature rates of change of less than 2°C per hour.

Rapid Response, Low Noise. Both are provided by the discontinuous digital filter which acts on the rate of input change. When a large input change is sensed with DAMPING OUT, the μP switches off its 3-pole digital filter to allow a fast reading update which will settle to ±0.012% of end range within 0.5 second. The filter is then switched on for low noise settling to the final value. DAMPING IN keeps the filter active at all times, eliminating discontinuities when the input changes rapidly.

Other Features

- The readout can be expanded from 5½-digit to 6½-digit resolution by pressing the HI RES pushbutton. 6½ digits are always available on the IEEE-488 bus.
- All front panel controls are programmable.
- Front panel annunciator lamps continuously update instrument status. This is particularly helpful in system applications.
- The isolated analog output can be set to represent either the four least significant digits or the four most significant digits of the displayed reading.
- The mV INPUT connector is manufactured with special low thermal EMF materials to minimize zero shifts and offsets.
- The ZERO control also serves as a baseline suppression, since all readings displayed are the difference between the stored baseline and the actual voltage.
- Standard cells and other delicate sources are not disturbed by the input resistance of 1GΩ and the 5nF input capacitance.

Calibration. The Model 262 low thermal voltage divider is designed for calibration of the 181 and sensitive DMMs. The 262 has voltage division ranges from 10^2:1 to 10^5:1 in steps of ×10. The accuracy at 10^2:1 is ±35ppm with stability of 2ppm/°C. The 262 is intended to be used with the customer's precision dc calibrator. A mating cable to the 181 is included.

Nanovoltmeter/181

System/Bench

DC VOLTS

RANGE	5½-DIGIT RESOLUTION	ACCURACY ±(%rdg + counts) 24 Hr., 22°-24°C	ACCURACY ±(%rdg + counts) 1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18°C & 28°-35°C	INPUT RESISTANCE	MAXIMUM ALLOWABLE INPUT	NMRR (LINE FREQUENCY)
2 mV	10 nV	0.006 + 5*	0.015 + 5*	0.002 + 3	>1 GΩ	120 V**	>90 dB
20 mV	100 nV	0.006 + 2*	0.015 + 2*	0.002 + 0.5	>1 GΩ	120 V**	>80 dB
200 mV	1 µV	0.006 + 2	0.015 + 2	0.002 + 0.2	>1 GΩ	120 V**	>80 dB
2 V	10 µV	0.004 + 1.5	0.007 + 2	0.0007 + 0.2	>1 GΩ	1000 V**	>60 dB
20 V	100 µV	0.004 + 1.5	0.01 + 2	0.0008 + 0.2	10 MΩ	1000 V	>60 dB
200 V	1 mV	0.004 + 1.5	0.01 + 2	0.0008 + 0.2	10 MΩ	1000 V	>60 dB
1000 V	10 mV	0.005 + 1.5	0.01 + 2	0.0012 + 0.2	10 MΩ	1000 V	>60 dB

*When properly zeroed. **10 seconds maximum; 35V rms continuous.

CMRR: 160dB on mV ranges, 140dB on V ranges; at dc and line frequency (50 or 60Hz).

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

PROGRAMMABLE PARAMETERS:
Front Panel Controls: Range, Filter, Zero, Damping, Hi Resolution.
Internal Parameters: SRQ Response, Trigger Modes, Data Terminators.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

TRIGGER MODES: One Shot: Updates output buffer once at first valid conversion after trigger on TALK and/or GET. **Continuous:** Updates output buffer at all valid conversions after trigger.

GENERAL

NOISE: <30nV p-p on lowest range with Filter on.

INPUT CAPACITANCE: 5000pF on mV ranges.

SETTLING TIME: 0.5s to within 25 counts of final reading w/Filter on, Damping off.

FILTER: 3-pole digital; RC=0.5, 1, or 2 seconds depending on range.

DISPLAY: Seven 0.5 in. LED digits with appropriate decimal point and polarity.

OVERLOAD INDICATION: Display indicates polarity and OFLO.

ANALOG OUTPUT: Accuracy: ±(0.15% of displayed reading + 1mV). **Time Constant:** 400ms. **Level:** ±2V full scale on all ranges; ×1 or ×1000 gain.

ISOLATION: Input LO to Output LO or power line ground: 1400V peak, 5×10^5V•Hz, $>10^{10}\Omega$ paralleled by 1500pF.

WARMUP: 1 hour to rated accuracy.

ENVIRONMENTAL LIMITS: Operating: 0°C to 35°C, 0% to 80% relative humidity. **Storage:** −25°C to 65°C.

POWER: 105-125V or 210-250V (internal switch selected), 50-60Hz, 30VA maximum.

INPUT CONNECTORS: Special low thermal for 200mV and lower ranges. Binding posts for 2V to 1000V ranges.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.85kg (8½ lbs.).

ACCESSORY SUPPLIED: Model 1506 Low Thermal Input Cable.

ACCESSORIES AVAILABLE:

Model 262:	Low Thermal Voltage Divider
Model 1019A-1:	5¼-in. Single Fixed Rack Mounting Kit
Model 1019A-2:	5¼-in. Dual Fixed Rack Mounting Kit
Model 1019S-1:	5¼-in. Single Slide Rack Mounting Kit
Model 1019S-2:	5¼-in. Dual Slide Rack Mounting Kit
Model 1483:	Low Thermal Connection Kit
Model 1484:	Refill Kit for 1483 Kit
Model 1485:	Female Low Thermal Input Connector
Model 1486:	Male Low Thermal Input Connector
Model 1488:	Low Thermal Shorting Plug
Model 1503:	Low Thermal Solder and Flux
Model 1506:	Low Thermal Input Cable (4 ft., clips)
Model 1507:	Low Thermal Input Cable (4 ft., lugs)
Model 1815:	Maintenance Kit
Model 8003:	Low Resistance Test Fixture

See page 85 for descriptions of all accessories.

Voltage Divider/262

Low Thermal

KEITHLEY 262 LOW THERMAL VOLTAGE DIVIDER
DIVIDER RATIO
POLARITY
WARNING: CONNECT CHASSIS TO EARTH DO NOT EXCEED 20VDC INPUT

- **Low thermal switching**
- **Input remote sense terminals**
- **Easy to operate**

The Model 262 Low Thermal Voltage Divider offers a convenient method for nanovoltmeter calibration. It provides the necessary thermal stability as well as the accuracy to calibrate the most sophisticated nanovoltmeters, such as Model 181. In addition, it takes the burden out of calibrating today's µV-sensitive DMMs.

The Model 262 is the only instrument of its kind with the thermal stability critical for these applications. It is intended to be used with precision voltage sources found in any calibration or metrology lab.

DIVIDER RATIO	ACCURACY (1 Year)* 22°-24°C	TEMPARATURE COEFFICIENT 18°-28°C	OUTPUT NOISE (0.1Hz Bw)	THERMAL DRIFT**
$10^2 : 1$	± 35ppm	2ppm/°C	10nV p-p	10nV
$10^3 : 1$	± 35ppm	2ppm/°C	10nV p-p	10nV
$10^4 : 1$	±100ppm	10ppm/°C	1nV p-p	3nV
$10^5 : 1$	±100ppm	10ppm/°C	1nV p-p	3nV

*Referenced to output terminals.

**For ambient temperature changes ≤1°C/hour. Includes effects of supplied cable.

CONTROLS: Polarity, divider ratio.

INPUT RESISTANCE: 20kΩ for divider ratios of 10^2:1 and 10^4:1; 200kΩ for divider ratios of 10^3:1 and 10^5:1.

OUTPUT RESISTANCE: 2Ω for divider ratios of 10^4:1 and 10^5:1; 200Ω for divider ratios of 10^2:1 and 10^3:1.

OVERLOAD PROTECTION: Maximum operating input voltage is 20V. Input is protected against 1000V overloads from calibrators with current limits up to 150mA.

CONNECTORS: Input: 5-way binding posts for input, sense, and case ground. **Output:** Special low thermal female connector; mates with 1506, 1507, 1481, 1482.

ENVIRONMENTAL LIMITS: Operating: 18°-28°C, 0 to 60% relative humidity. **Storage:** −25° to 65°C.

DIMENSIONS, WEIGHT: 114mm high × 165mm wide × 184mm deep (4½ in. × 6½ in. × 7¼ in.). Net weight 2kg (4½ lbs.).

ACCESSORY SUPPLIED: Model 262-315 low thermal male-to-male cable (3 ft.) for connecting to Model 181.

155/Microvoltmeter

Null Detector

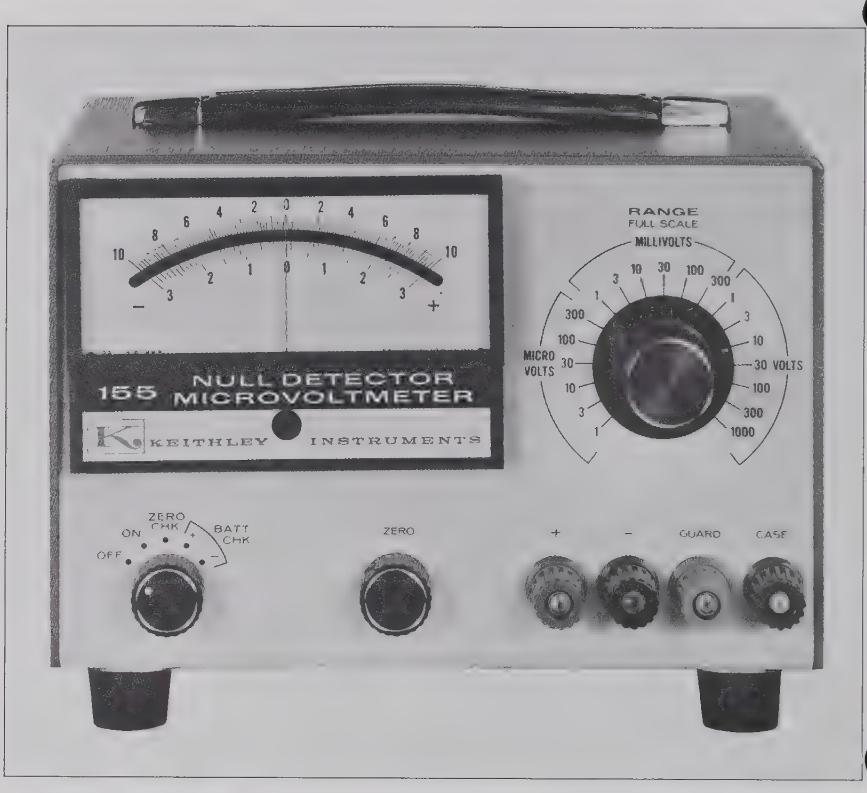
- **150nV to 1kV**
- **1000-hour battery life**
- **$10^{12}\Omega$ isolation**

The Model 155 Null Detector-Microvoltmeter is a high-performance, low-cost instrument with better than 150nV resolution and full-scale ranges up to 1kV. Its electrical and physical ruggedness, broad range, and high common- and normal-mode rejection make it one of the most versatile voltmeters available for applications in standards labs, development labs, production testing, and basic research.

As a null detector, the guarded battery-operated 155 is often used with potentiometers, bridges, Kelvin-Varley dividers, and for amplifier gain and linearity measurements. The 155 can recover from 100V overloads within 5 seconds on the 30mV and higher ranges. Up to 1200V peak may be applied momentarily on any range without damaging the instrument.

A ±1V at 1mA output is located on the rear panel for connection to recorders or other readout devices. Accuracy is ±2% of full scale at the meter and ±1% at the rear panel recorder output.

The 155 is designed for battery operation to minimize ground loop and high frequency pickup problems in sensitive voltage measurements. Four internally mounted standard batteries provide greater than 1000 hours of operation.



RANGE: ±1μV full scale to ±1000V on zero center meter in 19 overlapping 1× and 3× ranges.

ACCURACY: ±1% of full scale at recorder output, ±2% of full scale at meter, exclusive of noise and drift.

ZERO DRIFT: <0.5μV per 24 hours, typically <0.1μV per °C. Long term drift is non-cumulative.

METER NOISE: <0.03μV rms (0.15μV peak-to-peak) on most sensitive range with input shorted.

INPUT RESISTANCE: 100MΩ on 3V to 1kV ranges; 10MΩ on 300mV to 1V ranges; 1MΩ on 1μV to 100mV ranges.

NORMAL MODE REJECTION: An applied 50-60Hz signal which is 80dB greater than full scale peak-to-peak will not affect reading on most sensitive range (equivalent to 100dB NMRR). Rejection decreases to 20dB on the 10mV and higher ranges. Peak ac+dc must never exceed 1200V.

COMMON MODE REJECTION: Common mode voltage, dc or 50-60Hz, 120dB greater than full scale up to 1200V peak will not affect reading (equivalent to 140dB CMRR).

ISOLATION: $>10^{12}\Omega$ shunted by 0.01μF between chassis ground (case) and input LO at up to 50% relative humidity and 25°C.

RISE TIME (10%-90%): 1 second on 10μV range and above, increasing to 5 seconds on 1μV range.

ZERO SUPPRESSION: ±25μV.

RECORDER OUTPUT: ±1V at up to 1mA.

OVERLOAD: Up to 1200V peak may be applied momentarily on any range. Recovery from overload 10^6 times full scale for 1 second with 10kΩ source is within 5 seconds on the 30μV and higher ranges, increasing to 20 seconds on the 1μV range.

CONNECTORS: Output: Barrier strip. **Input:** Binding posts.

POWER: Four internally mounted carbon-zinc batteries (2N6) provide >1000 hours continuous operation. Barrier strip provided for external power supply.

DIMENSIONS, WEIGHT: 165mm high × 210mm wide × 185mm deep (6½ in. × 8¼ in. × 7¼ in.). Net weight 2.5kg (6 lbs.).

ACCESSORY SUPPLIED: Instruction manual.

Sourcing: An Introduction

Dc sources are fundamental to electronic circuits and devices. Their applications are varied but include:

DC Power: Circuit bias and operation.

DC Signal: Semiconductor parametric test; setting levels; reference and comparison; calibration; threshold detection; particle or beam deflection

Active Load: Sink power from device under test.

Keithley sources are more than just power supplies; they are dc instruments designed to supply precision voltage or current. Sources deliver performance over and above power supplies in one or more of these characteristics:

- Dynamic range of output
- Sensitivity
- Power source or sink
- Programmability
- Output impedance and isolation
- Transient response

Dynamic Range is important when testing semiconductor devices or a wide variety of diverse DUTs (see **Figure 1**). Values required for testing may span several decades of voltage or current. For the best accuracy and regulation of the output, it is important that the programmed value be greater than 20% of range.

All Keithley sources have multiple output ranges covering as many as 9 decades, as in the case of the Model 220 Current Source. This means that the optimum range for test accuracy and precision can be selected. Dynamic range provides flexibility to satisfy your present and future test requirements, and minimizes the need for multiple instruments.

Sensitivity. When sensitivity (small signals) is required, Keithley sources satisfy the need. Currents as low as 0.5 picoampere (10^{-12}A) and voltages down to 50 microvolts can be programmed under computer control. Further current sensitivity to 0.01 picoampere is available in the Model 261 Picoampere Source.

Source or Sink. Bipolar outputs allow setting of either positive or negative values on most Keithley sources. This bipolar operation simplifies test procedures and system design by eliminating the need for external switching or operator intervention to reverse the polarity of the output leads. In addition, these sources can act as an active load to a device under test such as a power supply, battery, or solar cell. The 4-quadrant capability (see **Figure 2a**) is ideal for charge/discharge cycle testing of batteries, applications in corrosion studies, and precision electroplating.

FIGURE 1: Semiconductor Parametric Test

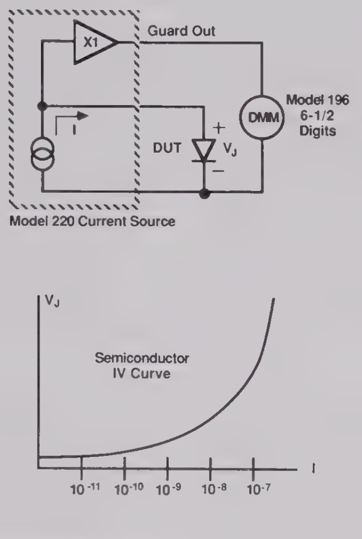


FIGURE 2a: 4-Quadrant Operation

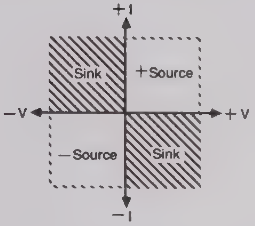
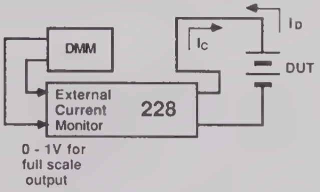


FIGURE 2b: Measuring Charge/Discharge Characteristics of Batteries



The power output capacity of Keithley sources ranges up to 100W in the Model 228. Power sink (dissipation) capacity equals the source capability, and is rated over the entire operating temperature range.

Programmability. System performance through an IEEE-488 interface is available on most Keithley sources (see Selector Guide). All front panel controls and settings are programmable, and a number of convenience capabilities such as hardware triggers, programmable delays, and internal program memory simplifies system integration.

Output Impedance. Keithley sources satisfy your need for near ideal output characteristics in critical applications. These sources go beyond power supply standards in achieving high isolation, low output offsets, and near ideal source impedance to assure minimum interaction and source effect in the test application.

For example, a guarded output **(Figure 1)** permits the use of a standard system DMM without affecting the $10^{14}\Omega$ output impedance of the Model 220 current source. Error contribution of the voltage follower amplifier is less than ±1mV. When used with a Model 6167 guarded input adapter, the guarded output also speeds circuit settling by compensating for shunt resistance and capacitance in the test cables.

Remote Sensing compensates for series resistance in the interconnect cabling. This assures that the full programmed voltage value is seen by the DUT.

Isolation. The outputs of Keithley sources are electrically isolated and can be floated above power line ground. This helps reduce the effects of ground loops, and can be used to achieve higher terminal voltages.

Transient Response. Keithley sources have been optimized for fast response. Most sources settle within milliseconds in response to changes in load or output value, and outputs are stable under a variety of load conditions.

Other Conveniences

- **Digital I/O:** Keithley programmable sources include several built-in lines of TTL compatible digital I/O. This added capability, which can be programmed and read back over the IEEE-488 bus, can be used for monitoring test system status or actuating external circuits.
- **Program Memory:** Some Keithley sources have memories which can be programmed with a sequence of output values. Once programmed, the sequence can be repeated in step fashion by issuing a trigger command to the source. This minimizes bus activity and improves system speed.

Source Application Areas:

- Semiconductor Parametric Analysis
- Materials Research
- Solar Cell Testing
- Battery Charge/Discharge Characteristics
- Relay and Resistive Component Testing
- Photomultiplier Tubes
- Calibration of Low Current Instruments
- Hall Effect
- Programmable Load
- Breakdown and Insulation Resistance Test

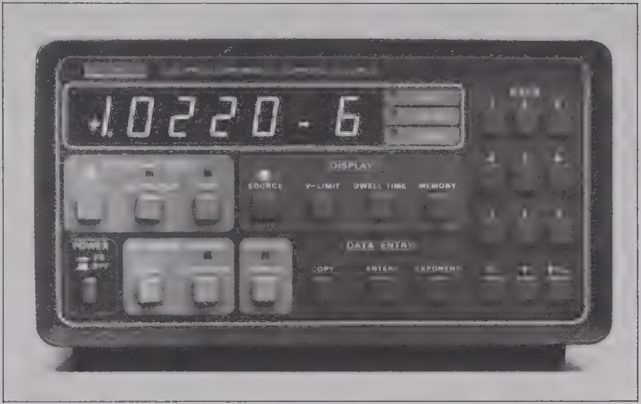
...and many more.

Keithley manufactures a broad range of compatible measurement and switching instruments. Check other sections in this catalog for your complete instrumentation needs.

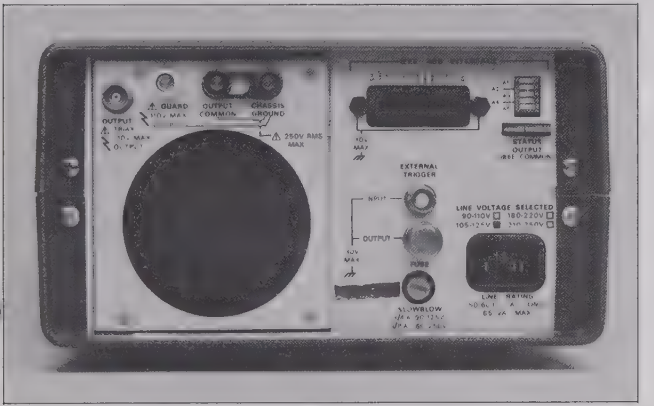
Selector Guide/Sources

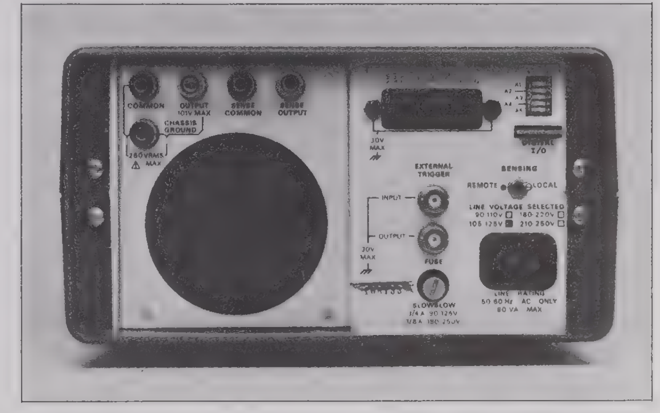
Model	**220**	**224**	**225**	**228**	**230**	**247**	**261**
Page	65	67	*	68	65	70	71
Current Source	✓	✓	✓	✓			✓
Voltage Source				✓	✓	✓	
Output: I	±(0.5pA to 100mA)	±(5nA to 100mA)	±(100pA to 100mA)	±(0.1mA to 10A)			±(0.01pA to 10μA)
V				±(4mV to 100V)	±(50μV to 100V)	±(1.5V to 3000V)	
Power	10W	10W	10W	100W	10W	18W	100μW
Limit Set: I				0.1mA to 10A	2, 20, and 100mA	6mA fixed	
V	1V to 100V	1V to 100V	10V to 100V	100V to 4mV			10mV to 11V
Source	✓	✓	✓	✓	✓	✓	✓
Sink	✓	✓		✓	✓		
Accuracy: Setting	0.05%	0.05%	0.5%	0.1%	0.05%	0.25%	0.5%
Programming	IEEE-488 Included	IEEE-488 Option 2243		IEEE-488 Included	IEEE-488 Included		
Features:							
Memory	100 pt.			100 pt.	100 pt.		
Trigger	In/Out	In/Out		In/Out	In/Out		
Remote Sense				✓	✓		
Guard	✓	✓					
Digital I/O	4 In/4 Out	4 In/4 Out		8 In/8 Out	4 In/4 Out		
Misc.				External Modulation		High Voltage	pA Calibrator

*See Substitution List in the back of this catalog.


1.0220-6
DISPLAY
SOURCE
V-LIMIT
DWELL TIME
MEMORY
POWER
DATA ENTRY
COPY
ENTER
EXPONENT

1.0230-0
PROGRAM MODE
SINGLE
CONTINUOUS
STEP
DISPLAY
MEMORY
POWER
PROGRAM CONTROL
OUTPUT
DATA ENTRY
EXPONENT


OUTPUT
GUARD
OUTPUT COMMON
CHASSIS GROUND
250V RMS MAX
STATUS OUTPUT
EXTERNAL TRIGGER
INPUT
OUTPUT
LINE VOLTAGE SELECTED
FUSE
SLOWBLOW
LINE RATING


COMMON
OUTPUT 101V MAX
SENSE COMMON
SENSE OUTPUT
CHASSIS GROUND
250VRMS MAX
DIGITAL I/O
EXTERNAL TRIGGER
SENSING
REMOTE
LOCAL
INPUT
OUTPUT
LINE VOLTAGE SELECTED
90-110V
180-220V
105-125V
210-250V
FUSE
SLOWBLOW
LINE RATING
50-60 Hz AC ONLY
80 VA MAX

MODEL 220 CURRENT SOURCE

- **±0.5pA to ±101mA dc output**
- **$10^{14}\Omega$ output resistance**
- **±1V to ±105V programmable V-LIMIT**

MODEL 230 VOLTAGE SOURCE

- **±50μV to ±101V dc output**
- **±2mA, ±20mA, ±100mA programmable I-LIMIT**
- **Remote sensing**

The demand on researchers, designers, and evaluation engineers for better device characterization has generated a widespread need for programmable, low-level dc sources. And, as an experienced manufacturer of automatic wafer measuring equipment, Keithley knows the importance to the user of instrument compatibility and ease of system integration. The 220 programmable current source and 230 programmable voltage source find major applications in semiconductor characterization, materials research, and ATE systems.

Both models incorporate a 100-step, programmable memory buffer, useful in applications where either a fixed number of outputs is repeated, or a complex waveform of discrete steps must be generated.

In system applications, the buffer can be loaded through the bus and the 220 or 230 can be commanded to sequence through memory while the controller is busy on other tasks.

The TRIGGER IN/OUT feature, when used in the STEP mode, allows the source to synchronize the measurements of other instruments such as the 619 electrometer/multimeter. The TRIGGER OUT occurs after the completion of dwell time; TRIGGER IN causes the 220 or 230 to advance to its next program step. This provides the capability to perform a preset source measurement without a computer.

Four TTL-compatible input and output (I/O) lines are provided on each model to receive and generate system commands. In a typical application, a source can be programmed to generate an SRQ (service request) to the controller if a system element such as a foot pedal switch, mechanical stop, or overtemperature condition is detected.

The I/O can provide a means for the customer to shut down the power supply for safety in a system environment. Digital I/O is an example of the convenience features that make the Models 220 and 230 easy to use in your test system.

MODEL 220 CURRENT SOURCE

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) 18°-28°C	STEP SIZE	TEMPERATURE COEFFICIENT/°C 0°-18°C & 28°-50°C
100 mA	±101.00 mA	0.1 % + 50 μA	50 μA	0.01 % + 2 μA
10 mA	±19.995 mA	0.05% + 10 μA	5 μA	0.005% + 200 nA
1 mA	±1.9995 mA	0.05% + 1 μA	500 nA	0.005% + 20 nA
100 μA	±199.95 μA	0.05% + 100 nA	50 nA	0.005% + 2 nA
10 μA	±19.995 μA	0.05% + 10 nA	5 nA	0.005% + 200 pA
1 μA	±1.9995 μA	0.1 % + 1 nA	500 pA	0.01 % + 20 pA
100 nA	±199.95 nA	0.3 % + 100 pA	50 pA	0.02 % + 2 pA
10 nA	±19.995 nA	0.3 % + 10 pA	5 pA	0.02 % + 200 fA
1 nA	±1.9995 nA	0.4 % + 2 pA	500 fA	0.02 % + 200 fA

OUTPUT RESISTANCE: $>10^{14}\Omega$.

OUTPUT CAPACITANCE: <20pF.

LINE REGULATION: <0.01% for ac power line changes within specified limits.

VOLTAGE LIMIT: Bipolar, 1 to 105 volts in 1V programmable steps.

RESPONSE TIME: <3ms to within 0.1% of programmed change.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy following any change in compliance voltage.

NOISE:

RANGE	NOISE (pk-pk of range)	3dB BANDWIDTH
100 mA	100 ppm	0.1 Hz to 30 kHz
100 nA to 10 mA	100 ppm	0.1 Hz to 100 Hz
10 nA	200 ppm	0.1 Hz to 10 Hz
1 nA	400 ppm	0.1 Hz to 10 Hz

GUARD OUTPUT:

Maximum Load Capacitance: 10nF.

Maximum Load Current: Absolute total (Output+Guard) not to exceed 105mA.

Accuracy: ±1mV (excluding output lead voltage drop).

PROGRAM MEMORY:

Number of Locations: 100.

Range of Dwell Times: 3ms to 999.9s.

Accuracy of Dwell Time: ±(0.05%+200μs).

OUTPUT LOAD: Output load must be non-inductive.

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Teflon® insulated triax connector (Specialty Connector #30JR121-1) for output; five-way binding posts for GUARD, OUTPUT COMMON, and CHASSIS: BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT, Amphenol or Cinch Series 87 IEEE and printed circuit digital I/O port. All connections on rear panel.

IEEE-488 BUS IMPLEMENTATION (220, 230)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

INTERNAL PROGRAMMABLE PARAMETERS: Display Mode, Output, Prefix Data Format, EOI, SRQ (including mask for over Limit), Program Mode, Range, Trigger Mode, Terminator Character, Inputs (Source, Limit, Dwell Time, 100-Point Memory Locations), Output Status, Digital Self Test.

DIGITAL I/O PORT: A separate I/O port consisting of four input and four output lines as well as common (IEEE-488) and +5V dc. Outputs will drive one TTL load. Inputs represent one TTL load. The 220 or 230 can be programmed to generate an "SRQ" upon *any* change in the four bit input data. Mating connector supplied.

MODEL 230 VOLTAGE SOURCE

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) 18°-28°C	STEP SIZE	TEMPERATURE COEFFICIENT/°C 0°-18°C & 28°-50°C
100 V	±101.00 V	0.05 % + 50 mV	50 mV	0.005% + 0.5 mV
10 V	±19.995 V	0.05 % + 10 mV	5 mV	0.005% + 100 μV
1 V	±1.9995 V	0.05 % + 1 mV	500 μV	0.005% + 25 μV
100 mV	±199.9 mV	0.075% + 300 μV	50 μV	0.01 % + 25 μV

MAXIMUM CURRENT LIMIT: ±100mA (−0, +20%).

SELECTABLE CURRENT LIMIT: ±100mA, ±20mA, ±2mA (−0, +20%).

LINE REGULATION: <0.01% for ac power line changes within specified limits.

NOISE: (150μV+50ppm range) p-p, 0.1Hz to 300Hz; 5mV p-p, 0.1Hz to 300kHz. Specification applies for local sensing only.

RESPONSE TIME: <3ms to within 0.1% of programmed change for Current Limit of at least 20mA.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy for Current Limit of at least 20mA.

OUTPUT IMPEDANCE:

SELECTED CURRENT LIMIT	OUTPUT IMPEDANCE
2 mA	1 mΩ+10 mH
20 mA	1 mΩ+ 2 mH
100 mA	1 mΩ+ 1 mH

SENSING: Rear panel switch selectable REMOTE and LOCAL sensing.

REMOTE SENSING:

Maximum Lead Drop: 0.5V.

Maximum Sense Lead Resistance: 5Ω. Specifications are per lead.

PROGRAM MEMORY:

Number of Locations: 100.

Range of Dwell Times: 3ms to 999.9s.

Accuracy of Dwell Time: ±(0.05% + 200μs).

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Five-way binding posts for OUTPUT, SENSE OUTPUT, COMMON, SENSE COMMON, and CHASSIS GROUND; BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT. All connections on rear panel.

GENERAL (220, 230)

DISPLAY: 0.5 in. LED digits, 4½-digit signed mantissa, 1-digit signed exponent.

SYSTEMS COMPATIBILITY: IEEE-488-1978.

LIMIT INDICATIONS:

Model 220 (Voltage Limit): "V-LIMIT" LED will blink.

Model 230 (Current Limit): "I-LIMIT" LED will blink.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGE (OUTPUT or OUTPUT COMMON to CHASSIS): 250V rms, dc to 60Hz.

SELF TEST: Digital RAM, ROM, optoisolators, front panel LEDs upon power ON.

WARMUP: 1 hour to rated accuracy.

POWER: 105-125 or 210-250V ac (internal switch selected), 50 or 60Hz, 60W maximum (80VA maximum). 90-105 or 180-210V ac operation available.

COOLING: Internal fan for forced air cooling.

ENVIRONMENTAL LIMITS: Operating: 0°-50°C; up to 35°C at 80% non-condensing relative humidity. **Storage:** −25° to 70°C.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.4kg (9 lbs. 11 oz.).

ACCESSORY SUPPLIED (220): Model 6011 Triaxial Test Lead (3 ft.). **(220, 230):** Instruction manual, programming guide.

Current Source/**224**

Programmable

- **±5nA to 101mA dc output**
- **$10^{12}\Omega$ output resistance**
- **Auto increment/decrement**
- **HI-LO limits for auto increment/decrement**
- **±1V to ±105V programmable V-LIMIT**

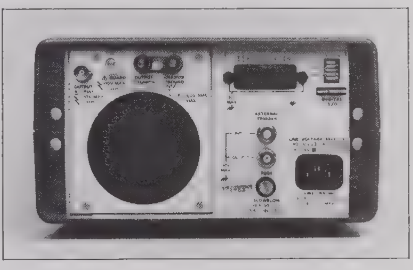
The Model 224 programmable current source was designed for general purpose bench or system use. The INCREMENT/DECREMENT function is manual or automatic, and selectable dwell times provide stepped ramp capabilities.

The Model 2243 IEEE-488 option is field installable. It allows flexible programming including current, V-LIMIT, local lockout, service request masks, and serial polling. A digital I/O port on the IEEE-488 interface card provides four TTL-compatible input and output lines. The status of the I/O port can be interrogated and changed over the bus.

The AUTO function allows automatic incrementing or decrementing of the output. Time per step can be set from 50ms/step to 999.9s/step.

+1.0224 -6
TALK
LISTEN
REMOTE
DATA
OUTPUT
OPERATE
CONTROL
AUTO
TRIG
DISPLAY
SOURCE
V-LIMIT
I-LIMIT
POWER
ON
OFF
DISPLAY MODIFY
DIGIT
INCR
DECR
DATA ENTRY
CANCEL
ENTER
EXPONENT

In some applications, it is necessary to limit the voltage across the device under test. The Model 224 offers compliance limit settings ranging from ±1V to ±105V in 1V steps. An SRQ on V-LIMIT can be programmed if the 2243 IEEE-488 option is installed. A blinking LED indicates V-LIMIT for bench operation.



ACCURACY

RANGE	MAXIMUM OUTPUT	ACCURACY (1 Year) ±(%rdg+offset) 18°-28°C	STEP SIZE	TEMPERATURE COEFFICIENT ±(%rdg+offset)/°C 0°-18°C & 28°-50°C
100 mA	±101.00 mA	0.1 + 50 µA	50 µA	0.01 + 2 µA
10 mA	±19.995 mA	0.05 + 10 µA	5 µA	0.005 + 200 nA
1 mA	±1.9995 mA	0.05 + 1 µA	500 nA	0.005 + 20 nA
100 µA	±199.95 µA	0.05 + 100 nA	50 nA	0.005 + 2 nA
10 µA	±19.995 µA	0.05 + 10 nA	5 nA	0.005 + 200 pA

OUTPUT RESISTANCE: $>10^{12}\Omega$. **OUTPUT CAPACITANCE:** <20pF.

LINE REGULATION: <0.01% for ac power line changes within specified limits.

VOLTAGE LIMIT: Bipolar, 1 to 105V in 1V programmable steps.

RESPONSE TIME: <3ms to within 0.1% of programmed change.

TRANSIENT RECOVERY TIME: <3ms to rated accuracy following any change in compliance voltage.

NOISE:

RANGE	NOISE (p-p of range)	BANDWIDTH
100 mA	100 ppm	0.1 Hz to 30 kHz
10 µA to 10 mA	100 ppm	0.1 Hz to 100 Hz

GUARD OUTPUT: Maximum Load Capacitance: 10nF.
Maximum Load Current: Absolute total (output+guard) ≤105mA.
Accuracy: ±1mV (excluding output lead voltage drop).

INCREMENT/DECREMENT: Automatic, manual or trigger modes.
Range of Dwell Times: 50ms to 999.9s.
Accuracy of Dwell Times: ±(0.05% + 200µs).
Step Size: Selected digit on a fixed range; minimum size 0.1% of range.
Current Limit: Maximum is ±full scale on range selected.

OUTPUT LOAD: Output load must be non-inductive.

EXTERNAL TRIGGER: TTL-compatible EXTERNAL TRIGGER INPUT and OUTPUT.

OUTPUT CONNECTIONS: Teflon insulated triax connector (Specialty Connector —30JR121-1) for output; five way binding posts for GUARD, OUTPUT COMMON and CHASSIS GROUND; BNC (chassis isolated) connectors for EXTERNAL TRIGGER INPUT and OUTPUT. All connections on rear panel.

IEEE-488 BUS IMPLEMENTATION (Model 2243 Option)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

INTERNAL PROGRAMMABLE PARAMETERS: Display Mode, Output, Prefix Data Format, EOI, SRQ (including mask for over V-Limit), Range, Terminator Character, Inputs (Source, V-Limit, Dwell Time), Output Status.

DIGITAL I/O PORT: A separate I/O port consisting of four input and four output lines as well as common (IEEE-488) and +5V dc. Outputs will drive one TTL load. Inputs represent one TTL load. The 224 can be programmed to generate an "SRQ" upon *any* change in the four bit input data. Mating connector supplied.

GENERAL

DISPLAY: 0.5 in. LED digits, 4½-digit signed mantissa, 1-digit signed exponent.

OVER VOLTAGE LIMIT INDICATION: "V-LIMIT" LED will blink.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGE (OUTPUT or OUTPUT COMMON to CHASSIS): 250V rms, dc to 60Hz.

SELF TEST: Digital RAM, ROM, and front panel LEDs upon power ON.

WARMUP: 1 hour to rated accuracy.

POWER: 105-125 or 210-250V ac (internal switch selected), 50 or 60Hz, 60W maximum (80VA maximum). 90-105 or 180-210V ac operation available.

COOLING: Internal fan for forced air cooling.

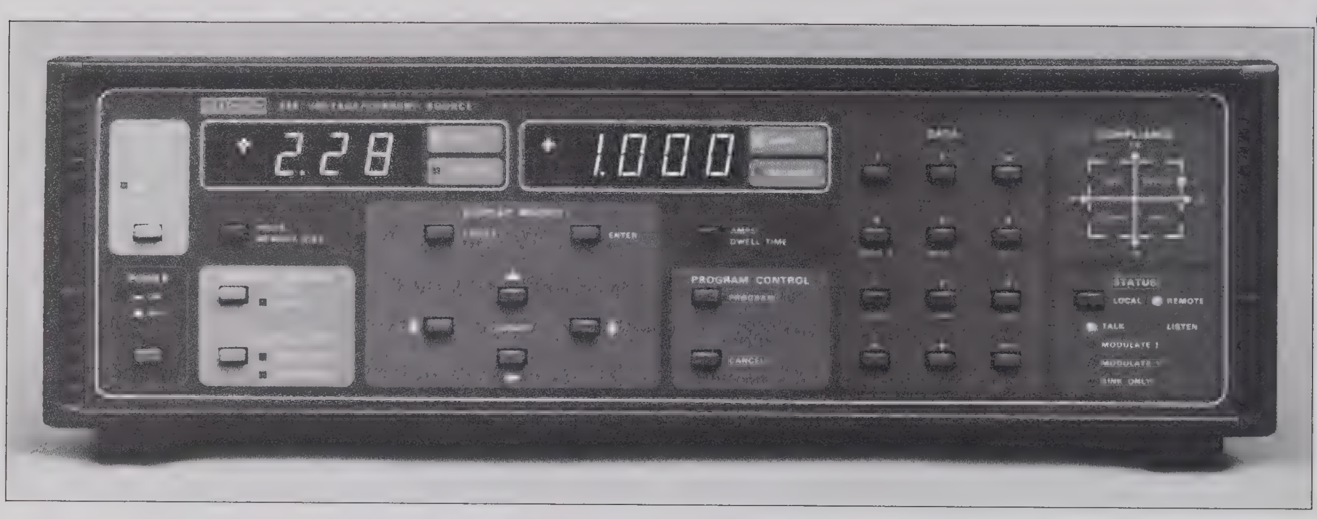
ENVIRONMENTAL LIMITS: Operating: 0°-50°C; up to 35°C at 80% non-condensing relative humidity. **Storage:** −25° to 70°C.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 4.5kg (9 lbs. 15 oz.).

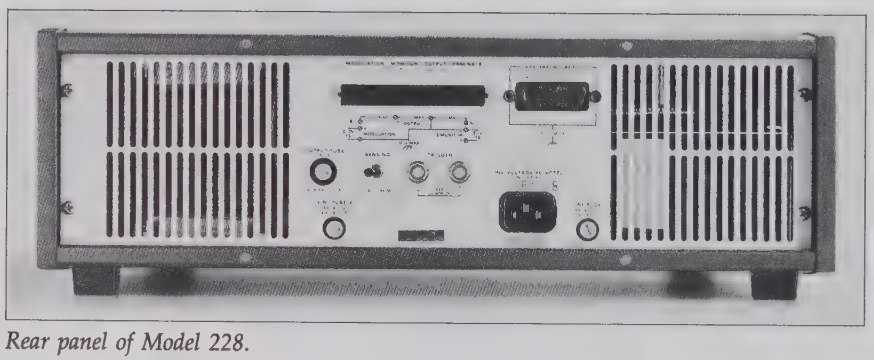
ACCESSORIES SUPPLIED: Model 6011 Triaxial Test Lead (3 ft.), instruction manual.

228/Voltage/Current Source

Programmable



- **100 watt sink or source**
- **<1ms transient recovery**
- **External modulation**
- **Built-in monitors**


Rear panel of Model 228.

The Model 228 is a precision programmable source with the capacity to sink or source up to 100 watts. Its six ranges accurately regulate a constant voltage or a constant current as determined by the load. And because it is two programmable sources in one (with built-in monitors), you get the flexibility for a broader range of test setups, without having to buy separate sources.

4-Quadrant Operation. The 228 is capable of bipolar source or sink up to a full 100 watts without derating in the sink quadrants, permitting it to act as a voltage or current supply or as an active load. Operating status is continuously shown on front panel LEDs.

The 228's modulation input allows voltage programming. Dc to 600Hz inputs can be used to vary the output within the full scale range of the source, simulate variable load conditions in sink, provide a power boost, or test power supply rejection.

Fast Response. Load transient recovery time is less than 1ms, without troublesome overshoot or oscillation.

Voltage and Current Monitor. The actual output voltage and current are continuously monitored and displayed on the front panel. These values can also be read back over the IEEE-488 bus, eliminating the need for separate measurement instruments in many situations.

Switch-selectable remote sensing assures the full rated voltage accuracy at the device under test, even when delivering high currents. And our unique safety disconnect design eliminates dangerous external terminal blocks and barrier strips.

Fully Programmable. The IEEE-488 interface is standard with the 228, and all front panel controls and capabilities are available over the bus. TRIGGER IN/OUT enables synchronization with other components in your test setup, and the programmable dwell time allows settling before TRIGGER OUT is issued.

The 228 checks its own operation and provides diagnostic error messages. An SRQ can be programmed to alert the system of many operating conditions. All output parameters can be pre-programmed in the internal 100-point memory, allowing you to step through repetitive test sequences with minimal bus activity. The battery maintained memory can retain programmed data through power down, brownout, or even a month or more in storage.

The 228 joins the popular 220, 224, and 230 Sources in the growing Keithley line of compatible, modular programmable instruments. Easy operation and simple, consistent command syntax assure you of fast, reliable test setups—every time.

Programmable

AS A CONSTANT VOLTAGE SOURCE

	OUTPUT			COMPLIANCE (Source or Sink)		
RANGE	MAXIMUM	RESOLUTION	ACCURACY* (1 Year) 18°-28°C	MAXIMUM	RESOLUTION	ACCURACY (1 Year) 18°-28°C
100 V	±101.0 V	100 mV	±(0.1% + 0.1 V)	±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400 µA)
10 V	±10.10 V	10 mV	±(0.1% + 10 mV)	±10.10 A	10 mA	±(0.5% + 40 mA)
				±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400 µA)
1 V	±1.010 V	1 mV	±(0.1% + 1.0 mV)	±10.10 A	10 mA	±(0.5% + 40 mA)
				±1.010 A	1 mA	±(0.1% + 4 mA)
				±0.1010 A	100 µA	±(0.1% + 400 µA)

*Above 0.4% of range.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.1 × applicable accuracy specification)/°C.

NOISE:

RANGE	0.1-300 Hz	0.1-300 kHz	0.1-20 MHz
100 V	5.0 mV p-p	15 mV p-p	25 mV p-p
10 V	2.0 mV p-p	15 mV p-p	25 mV p-p
1 V	0.7 mV p-p	15 mV p-p	25 mV p-p

OUTPUT RESISTANCE (max.): 100V Range: 10mΩ. 10V Range: 100µΩ. 1V Range: 100µΩ.

OUTPUT INDUCTANCE: 100µH typical.

SENSING: Rear panel switch selectable REMOTE and LOCAL sensing.

REMOTE SENSING: Corrects for up to 0.5V drop per output lead. Maximum 5Ω per sense lead for rated accuracy. Maximum 0.5Ω per sense lead for rated output resistance.

AS A CONSTANT CURRENT SOURCE

	OUTPUT (1 Year, 18°-28°C)			COMPLIANCE (Source or Sink)		
RANGE	MAXIMUM	RESOLUTION	ACCURACY* (1 Year) 18°-28°C	MAXIMUM	RESOLUTION	ACCURACY (1 Year) 18°-28°C
10 A	±10.10 A	10 mA	±(0.5% + 10 mA)	±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)
1 A	±1.010 A	1 mA	±(0.1% + 1.0 mA)	±101.0 V	100 mV	±(0.1% + 400 mV)
				±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)
0.1 A	±0.1010 A	100 µA	±(0.1% + 0.1 mA)	±101.0 V	100 mV	±(0.1% + 400 mV)
				±10.10 V	10 mV	±(0.1% + 40 mV)
				±1.010 V	1 mV	±(0.1% + 4 mV)

*Above 0.4% of range.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±(0.1 × applicable accuracy specification)/°C.

NOISE:

RANGE	0.1-300 Hz	0.1-300 kHz	0.1-20 MHz
10. A	25 mA p-p	25 mA p-p	25 mA p-p
1 A	5 mA p-p	5 mA p-p	25 mA p-p
0.1 A	0.5 mA p-p	2 mA p-p	3 mA p-p

OUTPUT RESISTANCE (min.): 10A Range: $10^4\Omega$. 1A Range: $10^5\Omega$. 0.1A Range: $10^6\Omega$.

OUTPUT CAPACITANCE: 0.2µF typical.

OUTPUT LOAD: Must be non-inductive.

CURRENT MONITOR OUTPUT

SCALE FACTOR: 1V = 100% of range.

ACCURACY: Same as constant current mode.

BANDWIDTH: 5kHz typical.

OUTPUT RESISTANCE: 10kΩ.

EXTERNAL MODULATION

INPUT RESISTANCE: 6.8kΩ.

SENSITIVITY: −10V increases magnitude of programmed output by 100% of full scale; +10V decreases magnitude of programmed output by 100% of full scale.

ACCURACY: 2% typical, dc to 60Hz.

MAXIMUM MODULATION: Modulation and programmed setting should not cause operation exceeding the range of 0 to 100% of full scale.

MODULATION FREQUENCY: 600Hz bandwidth.

IEEE-488 BUS IMPLEMENTATION (IEEE-488-1978)

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Output (Operate or Standby), Range, Voltage, Current, Trigger Mode, Sink, Modulation (Voltage or Current), Display Mode, Output Prefix (data format on readback), SRQ Mask, EOI, Terminator Characters, Status, Self Test, Memory Location (100 point memory), Dwell Time.

GENERAL

DISPLAY: Dual 3½-digit LED (0.5 in.) displays indicate programmed values in Standby and output values in Operate.

FRONT PANEL PROGRAMS: COPY, SINK, IEEE Address, MOD V, MOD I, TEST, RESET.

READBACK ACCURACY: Same as output accuracy.

LOAD TRANSIENT RECOVERY TIME: With a resistive load the output will recover 90% of any load changes within 1ms after end of changes, provided the changes do not cause transfer to another control mode.

STANDBY: Programs output to 0V, 0A without changing ranges or polarity.

LINE REGULATION: <0.01% output change for ac power line changes within specified limits.

PROGRAM MEMORY (battery backed-up): Stores up to 100 output settings. **Range of Dwell Times:** 20ms to 1000s. **Accuracy of Dwell Times:** ±(0.05% + 2ms).

BATTERY BACKUP: Rechargeable 3.6V nickel-cadmium. 1 month retention of data with unit turned off.

TRIGGER: IN and OUT TTL-compatible.

PROGRAMMING RESPONSE TIME: <100ms on fixed range (typical).

MAXIMUM COMMON MODE VOLTAGE (output or output common to chassis): 100V dc.

OUTPUT CONNECTIONS: Quick disconnect card with screw terminals for output, modulation, current monitor, and external sense. BNC (chassis isolated) connectors for TRIGGER IN/OUT.

SELF TEST: Analog and digital circuits tested at power-on. Power supplies, temperatures, and output continuously monitored.

WARMUP: 10 minutes to rated accuracy.

COOLING: Internal fan for forced air cooling.

POWER: 105-125 or 210-250V ac (internally switch selectable), 50 or 60Hz, 500VA maximum.

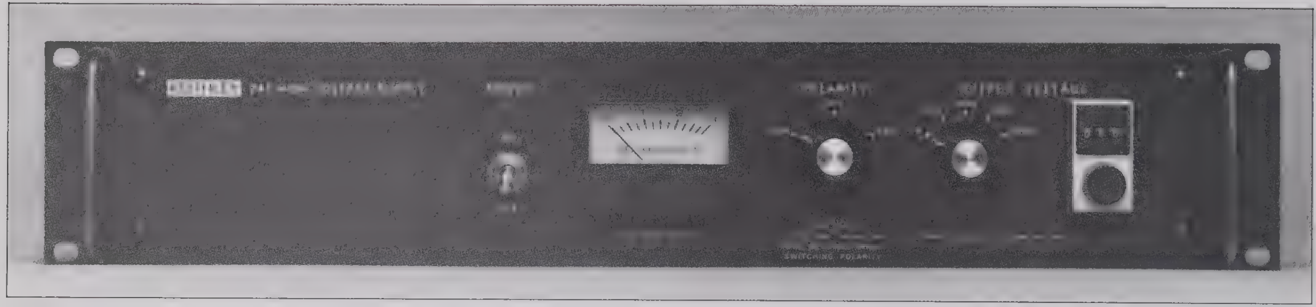
ENVIRONMENT: Operating: 0° to 50°C, <80% non-condensing RH below 35°C. **Storage:** −25° to 70°C.

DIMENSIONS, WEIGHT: 133mm high × 435mm wide × 448mm deep (5¼ in. × 17⅛ in. × 17⅝ in.). Net weight 10.9kg (24 lbs.).

ACCESSORIES SUPPLIED: Output connector, instruction manual.

247/Power Supply

High Voltage



- **High stability**
- **Excellent line and load regulation**
- **Bench or rack mounting**

The Model 247 High Voltage Supply is a highly regulated 3000V dc, 6mA supply that complements the superior sensitivity characteristics of Keithley electrometers and picoammeters in applications such as photomultiplier tubes, resistivity testing, ion chambers, and other nuclear detectors.

Output Precision. The Model 247 has an output current of 6mA, sufficient to operate several devices at one time. The output stability of 0.01% per hour facilitates long term measurements. Any output voltage from 0 to 3000V may be set with 200mV resolution. The polarity reversal switch is particularly useful in resistivity testing.

Line Regulation. Sensitive measurements will not be disturbed by fluctuating line voltage, due to superior line regulation. A 10% line change causes less than 0.001% output change.

Low Noise. Low ripple and noise of 3mV p-p at 1kV, 1mA minimizes noise contribution to capacitive circuits such as ion chambers and resistivity cells.

Bench or Rack Mounting. The Model 247 is supplied with accessory mounting feet for bench applications. Rack mounting is accommodated by the 19-inch spaced holes in the front panel.

Solid State Design. Long life and low maintenance costs can be anticipated from the 247 due to its all solid state design. Output circuitry is protected against arcs and short circuits.

OUTPUT:
  Voltage: 0 to 3kV dc.
  Current: 6mA dc maximum.
  Polarity: Positive or negative with respect to chassis.

ACCURACY: ±(0.25% of setting + 1.5V dc) from 18° to 28°C.

RESOLUTION: Dial graduations of 200mV.

STABILITY: ±0.01% of setting/hr.; ±0.02% of setting/8 hrs., at constant temperature after ½ hour warmup.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): ±50ppm/°C.

LINE REGULATION: 0.001% voltage change for 10% line variation.

LOAD REGULATION: 0.005% voltage change from no load to full load.

RIPPLE AND NOISE: 3.5mV rms, 10mV p-p @ 3kV, 6mA; 1mV rms, 3mV p-p @ 1kV, 1mA, 10Hz-100kHz.

SETTLING TIME: 4 seconds to within 1V with full resistive load.

OVERLOAD PROTECTION: Short circuit proof, arc protected, self restoring.

METER: Monitors voltage output.

ENVIRONMENT: Operating: 0° to 50°C, 0 to 80% relative humidity up to 35°C. **Storage:** −40° to 75°C.

CONNECTOR: Rear panel, MHV Type UG-931/U.

POWER: 90-125V/180-250V, 50-60Hz, 130VA.

DIMENSIONS, WEIGHT: 483mm wide × 89mm high × 273mm deep (19 in. × 3½ in. × 10¾ in.), excluding handles. Four holes spaced for rack mounting. Net weight 5.9kg (13 lbs.).

ACCESSORIES SUPPLIED: Mating connector, UG-932/U; mounting feet for bench operation.

Picoampere Source

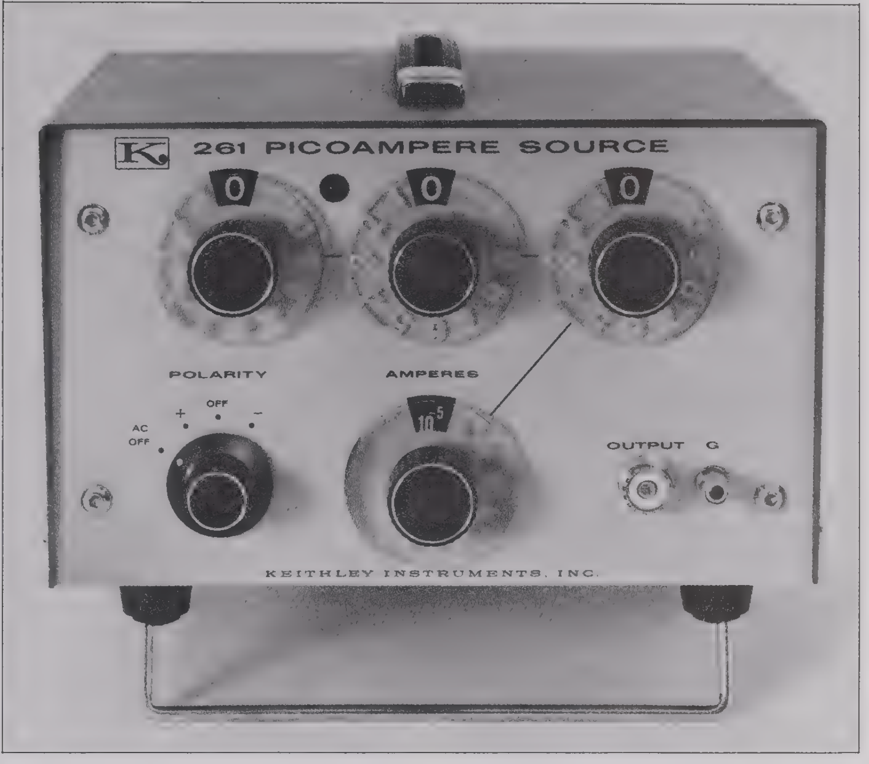
- **Output from 10^{-14}A to 1.1 ×10^{-4}A**
- **±0.25% accuracy at 10^{-7}A, ±0.7% at 10 × 10^{-12}A**
- **Secondary calibration standard**

The Model 261 Picoampere Source is a secondary standard for calibration of picoammeters and electrometers. It is a "passive" source, consisting of a selectable 0 to 10V voltage in series with a specially selected and tested hi-meg resistor.

Current output is 10^{-14}A to 1.1 × 10^{-4}A. Accuracy varies from ±(0.25% + 1 count) on 10^{-7} and higher ranges to ±(1.6% + 1 count) on the 10^{-11} range. Long term stability is better than ±0.15% per month (typically ±0.05% to ±0.1% per month) on the most sensitive ranges, beyond three months after calibration. Calibration maintains stated accuracy for three months.

The 261 may also be used as a decade resistance standard, having ±0.02% accuracy at $10^5\Omega$, ±0.1% accuracy at 10^6 and $10^7\Omega$, and ±0.5% accuracy at 10^8 through $10^{12}\Omega$.

The characterization of the hi-meg resistors is based on a 10-year Keithley program of collecting data on these components, and on individual time stability measurements of each resistor.



A calibration certificate including range resistor values, temperature coefficients, and temperature and date of calibration is furnished with each Model 261. Certification traceable to the National Bureau of Standards and recalibration are also optionally available.

OUTPUT: 10^{-14}A (10^{-11}A full range) to 1.1 × 10^{-4}A, positive or negative, in eight decade ranges.

ACCURACY: Exclusive of input drop consideration:

RANGE SETTING	SPAN, AMPERE	ACCURACY WITH 10.00 SETTING (10V SOURCE VOLTAGE)	WORST-CASE WITH SETTING OTHER THAN 10.00*
10^{-7} to 10^{-5}	10^{-7} to 1.1 × 10^{-4}	±0.25%	±0.25%
10^{-8}	10^{-8} to 10^{-7}	±0.5 %	±0.5 %
10^{-9}	10^{-9} to 10^{-8}	±0.6 %	±0.8 %
10^{-10}	10^{-10} to 10^{-9}	±0.6 %	±1.1 %
10^{-11}	10^{-11} to 10^{-10}	±0.6 %	±1.3 %
10^{-12}	10^{-12} to 10^{-11}	±0.7 %	±1.6 %
10^{-12}	10^{-14} to 10^{-12}	—	±2.0 %

*All accuracies are ± the percentage given, ±0.01×range switch setting.

LONG-TERM STABILITY: Will operate within stated specifications for three months after calibration. After three months add 0.15% per month to 10^{-8} through 10^{-12}A range setting accuracy specifications.

TEMPERATURE COEFFICIENT: ±0.1%/°C from 15°C to 30°C on 10^{-7} to 10^{-5}A range settings. Approximately 0.15%/°C on 10^{-12} to 10^{-8}A range settings. Exact values for these ranges supplied with instrument.

WARM-UP TIME: 1 hour.

LINE REGULATION: 0.001% for 10% change in line voltage.

SOURCE VOLTAGE: 0.00 to 11V in 0.01V steps.

RESOLUTION: 3 significant figures from 10^{-12}A to 1.1 × 10^{-4}A.

RANGE RESISTORS: 10^5 to $10^{12}\Omega$ in decade steps; ±5%.

RANGE RESISTOR ACCURACY: Value with power on, given on certificate.
±0.5 %: 10^8 to $10^{12}\Omega$
±0.1 %: 10^7 to $10^6\Omega$
±0.02%: $10^5\Omega$.

OUTPUT ISOLATION: Low to ground: $>10^9\Omega$ shunted by 0.001µF.

CERTIFICATION: A Calibration Certificate is furnished including range resistor values, thermal coefficients, temperature and date of calibration. Certification traceable to the National Bureau of Standards is also available.

POWER: 105-125V or 210-250V (switch selected), 50-60Hz, 6W.

DIMENSIONS, WEIGHT: 155mm high × 225mm wide × 300mm deep (6¼ in. × 9 in. × 12 in.). Net weight 4.1kg (9 lbs.).

ACCESSORY SUPPLIED: Model 2611 Test Cable.

Switching: Key To System Integrity

Achieving required system accuracies and precision at the DUT (Device Under Test) interface is not a trivial matter. It requires selection of appropriate instruments, creativity in designing test methods, and careful attention to specifications and error terms. This discipline must include consideration of the error contribution from the system switch and interconnect wiring.

Most test system designs are complex enough that it is in the designer's best interest to minimize the number of uncontrolled variables. To accomplish this, the system switch performance should be tightly specified.

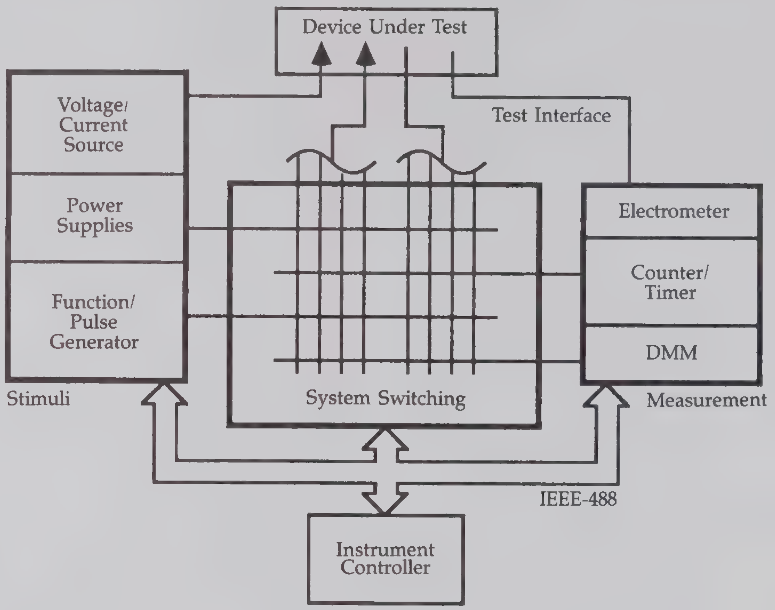
Special consideration should be given to the tests which approach the specified limits of accuracy, resolution, or sensitivity of the measurement or sourcing instruments. These generally represent the ''most critical test requirements'', and the switching should be selected to support these tests without introducing significant additional error. A system designed to perform against the ''most critical test requirements'' will usually satisfy other test requirements as well.

Selecting the Right Switch

The first consideration in choosing a switching instrument for your test system is to match the system's critical test requirements against the specified performance of the witch. If the requirement is to measure a 1 volt reference to 1 microvolt, be certain that the thermal offset voltage of the system switch is not hundreds of microvolts. If switching of power supply voltage is required, be certain that the switch has sufficient current carrying capacity. When measuring resistance below 1 kilohm through the system, be certain that the switch will support 4-wire measurements.

Unfortunately, there is no universal switch that satisfies all requirements simultaneously. A variety of different switches matched to test needs may be required. Fortunately, Keithley can help with the broadest range of fully specified switching performance in the industry.

FIGURE 1: General Purpose Test System



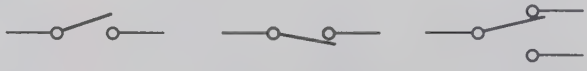
Types of Switching

Switching Configuration can be described according to the type of electrical property being switched, by its mechanical construction, or by its function in the test system (**Figure 2**). These represent descriptions of the signal paths or electrical interconnects available with the switch, and are necessary for laying out and wiring the test system. However, they do nothing to describe the electrical performance or specifications of the switch.

Matrix Switching is the most versatile type of system switching. The convenience of the matrix switch is that any input can be connected to any output, singly or in combination. This means

FIGURE 2: Switching Configurations

Electrical Property	Voltage Switching	Normally open, path interrupted
	Current Switching	Normally closed, path maintained
Mechanical Construction		



Form A: SPNO
(Single Pole
Normally Open)

Form B: SPNC
(Single Pole
Normally Closed)

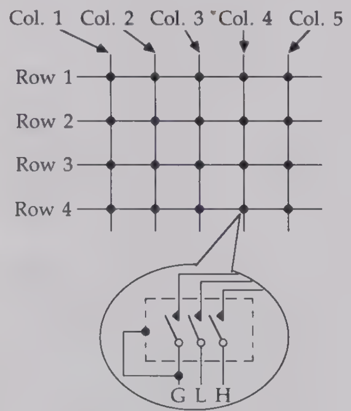
Form C: SPDT
(Single Pole
Double Throw)

Function	Scanner	Sequential switching of multiple inputs to one output
	Multiplexer	Random switching of one input to multiple outputs
	Actuator	Random access, independent isolated relays (one input to one output)
	Matrix	Random access switching of multiple inputs (rows) to multiple outputs (columns)

that multiple instruments or sources can be connected to any DUT pin, thereby minimizing the need for complex wiring and interconnect systems. The use of matrix switching can also help to simplify the DUT interface.

Keithley's matrix switch, the Model 7052 (page 77), has three poles of switching at each crosspoint to connect input HI, LO, and GUARD to the corresponding output. Specially constructed relays keep offset currents below 100pA, and the use of switched guard assures isolation between channels. In addition, the use of selected dry reed relays maintains contact potential below $20\mu V$.

FIGURE 3: Model 7052 Matrix Switch



Each cross point in the matrix consists of a 3-pole Form A (normally open) relay. Shield of each relay is connected to the column GUARD line.

The matrix can be configured through external connections in any combination of 4×5. Multiple cards expand the matrix capacity to 200 crosspoints within a single Model 706 mainframe. Master/Slave operation allows for control of up to 1000 crosspoints on a single IEEE-488 address.

FIGURE 4: Switching Performance Characteristics

Characteristic	Necessary For:
Contact Potential	Precision measurement of voltage signals below 1V, as in reference testing, drift testing, and temperature coefficient testing
Current Offset	Measurement of signals below $1\mu A$, as in semiconductor characterization and insulation resistance tests
Characteristic Impedance	Signal integrity in RF switching
Thermocouple Reference	Accurate measurement of thermocouple sensor devices
Four Wire	Precision measurement of resistances below 1kΩ and switching of remote sensed voltage supplies
Maximum Current	Switching of power supplies and high power circuits
Maximum Voltage	Isolation and safety in high voltage systems

Electrical Performance

System switching must often be optimized for one particular performance characteristic to achieve minimum error contribution. Some of these characteristics are shown in **Figure 4**; Keithley has switches for even the most difficult requirements.

Mainframe Capabilities

The switching mainframe provides a convenient mechanical and programming environment for your Keithley switching cards. It can be selected to suit the size of the system, with either the two-slot Model 705 or the ten-slot Model 706. Any one of the 17 different varieties of switching cards can be put into any of the slots. Each card is surrounded by electrical shielding to effectively eliminate noise coupling between sensitive circuits.

Expansion for larger systems is as simple as connecting a standard coaxial cable to the serial programming loop. This allows up to four additional mainframes to be controlled in a slave configuration without consuming valuable IEEE-488 addresses.

Programming of Keithley switching mainframes allows for several different operating modes, trigger sources, and delays to unburden your IEEE-488 controller or PC for better task management and data handling. The instrument can be set to:

- Scan a range of channels at programmed intervals.
- Randomly close or open multiple relays.
- Issue a "Ready" signal to a measurement instrument.
- Read out date and time from its real-time clock.
- Inspect the programmed status of all switches and report closures.

...and much more.

Setup Memory permits the non-volatile storage of up to 75 separate switching configurations in the Model 706 mainframe (5 in the Model 705). These setups can be recalled with a short command to access the memory location rather than retransmitting state changes for all of the affected relays.

Digital I/O is built-in for your convenience. Eight TTL-compatible inputs and eight outputs can be programmed through the IEEE-488 interface to monitor status, interrupt on state changes, or control external logic circuits and devices. It is available at the rear panel on a separate card edge connector, so there's no need to use one of the system card slots.

Applications Support. Trying to do something unusual? Ask our experienced applications engineers. They would be happy to assist in selecting the appropriate switching to suit your application.

Switching System Solutions

Keithley scanners and switching cards are the building blocks with which you can configure a simple or sophisticated automated measurement system. The variety of switching cards and the card capacities of the Models 705 and 706 Scanners allow the system to be optimized for economy, measurement precision, future expansion, sensitivity, or any of a number of other criteria. Regardless of the need, the solution can be found in Keithley's line of switching products.

Select From 17 Switching Cards. Keithley switching cards are designed for the intendd application with signal handling capability that includes:

- Low voltage switching to 20 nanovolts
- Low current switching to 10 femtoamps
- High frequency switching to 500MHz
- Thermocouple switching with a precision temperature reference
- High voltage switching to 1000V

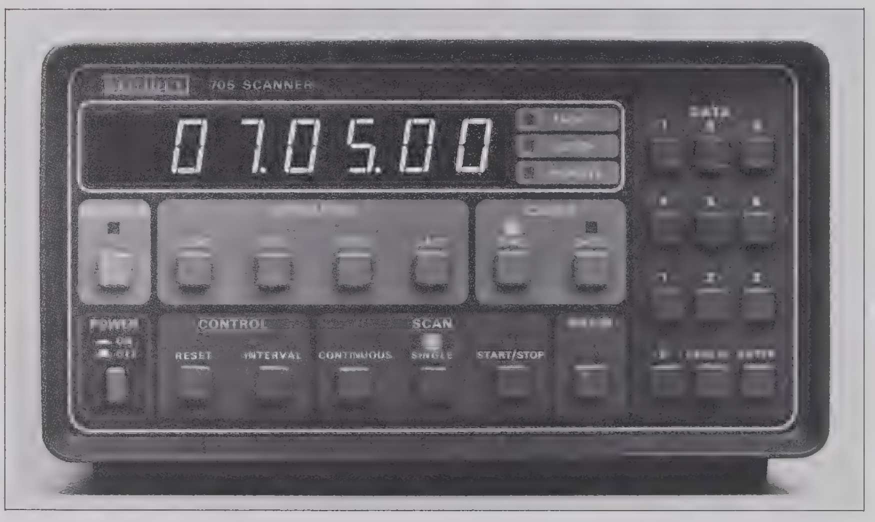
Of course, we offer general purpose and matrix switching, too. (See the Switching Cards Selector Guide on page 76 and individual switching card specifications for full details.)

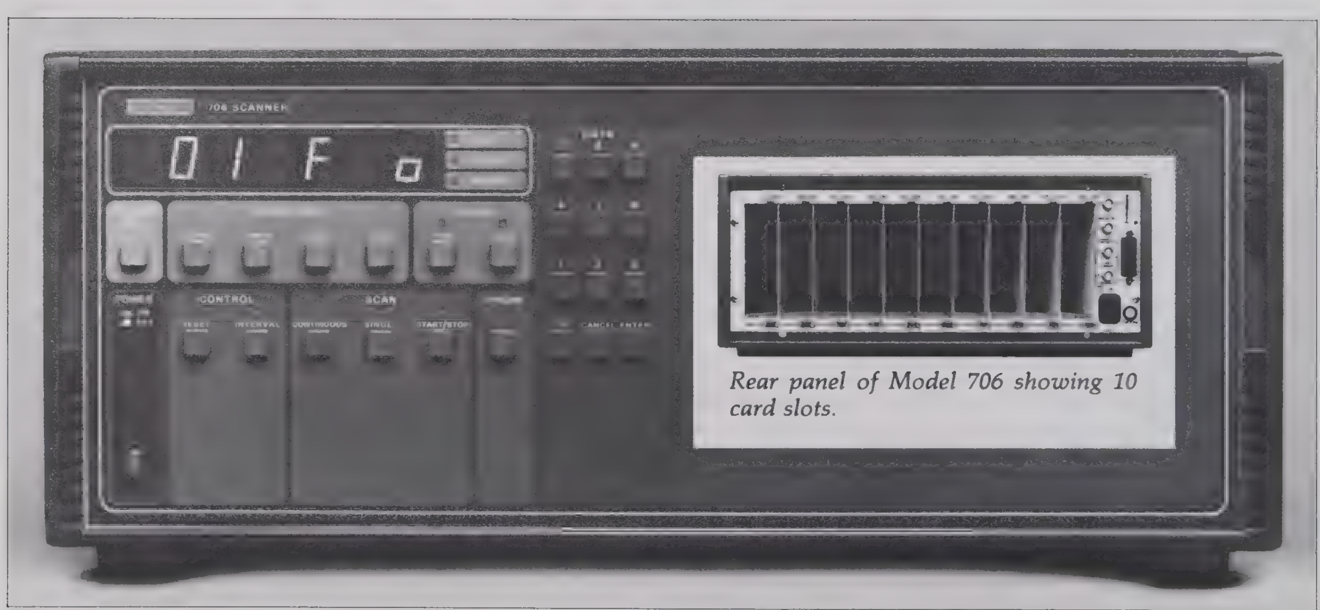
This signal handling capability alone sets Keithley apart as the leader in system switching. Now there is no reason to compromise your system's performance—simply select the switch to suit the application.

System Expansion. When switch requirements grow beyond the capacity of one Model 705 or 706 scanner mainframe, either can be expanded using additional mainframes in a Master/Slave configuration. In this operating mode, up to 4 Slave mainframes can be operated under the control of one Master through a serial loop connection at the rear. This simplifies programming and uses only one IEEE-488 address.

System Control. Each scanner mainframe includes an IEEE-488 interface port for simple and direct computer control. All front panel capabilities are available over the bus, as well as status, service request interrupts, control, and readback from the built-in digital I/O.

Hardware triggers allow synchronous operation with other system instruments or semi-automated control via operator input. The TTL-compatible EXTERNAL TRIGGER steps the mainframe to the next channel in sequence. CHANNEL





Rear panel of Model 706 showing 10 card slots.

READY provides a pulse output to other instruments at the completion of the programmed settling time.

Switching Modes. Operation of the scanner mainframes can be set to *1-pole, 2-pole, 4-pole, or matrix programming* depending on the switching cards selected.

Scanning can be set to sequence between programmed First and Last channels in a step, sweep, or continuous manner. The interval between channels is programmable in single or continuous scanning modes. The interval between channels in the step mode is determined by the trigger signal.

Random access switch closures can be programmed by simply entering the channel number to be closed. Any number of channels may be closed at one time; this is particularly important for matrix operation.

Setup Memory. The memory in a Keithley scanner mainframe can Store and Recall sets of relay configurations. Using the memory minimizes bus transfers by permitting a series of relay setups to be down loaded to the instrument's memory. Then any setup can be recalled by calling up the memory location. Five memory locations are available in the Model 705, and 75 non-volatile locations are in the Model 706 (setups are retained through power down).

An Inspect capability in the Model 706 allows the examination of all relay closures in any memory location. This status can also be read back over the IEEE-488 bus.

MODEL 705

- **2 switching card capacity**
- **Economy**
- **Bench and small systems**
- **20 channels/mainframe**

The Model 705 has capacity for two switching cards, allowing up to 20 channels of 2-pole switching (expandable to 100 channels). A built-in day/time clock, IEEE-488 interface, and direct front panel control make the 705 ideal for bench or workstation measurements.

MODEL 706

- **10 switching card capacity**
- **Expandable to 500 channels**
- **Large system applications**
- **Memory stores 75 configurations**
- **Inspect mode**

The Model 706 has capacity for 10 switching cards, allowing up to 100 channels of 2-pole switching or 200 matrix crosspoints. The matrix memory stores up to 75 sets of complex relay closures, and recalls any one by selecting the memory location or in sequence through the step scan control. A digital I/O port with 8 lines out is convenient for monitoring or controlling some external system parameters.

CAPACITY: 705: Two plug-in cards per mainframe. **706:** Ten plug-in cards per mainframe.

EXPANSION CAPACITY: Daisy chain allows up to 4 slave units with 1 master unit.

SWITCHING RATE: 100 channels/second (10ms), programmable to 1 channel/16 minutes (999.999 seconds).

RELAY DRIVE: 705: 350mA minimum. **706:** 4A minimum.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Display Mode, Output Format, EOI, SRQ, First, Last, Open, Close, Display Channel, Alternate Output, Pole Mode, Date Format, Save/Restore, Reset, I/O Port, Date, Settling Time, Interval Time, Alarm Time, Program Mode, Trigger Mode, Terminator, Self Test.

DIGITAL I/O PORT: A separate I/O port consisting of eight input and eight output lines as well as common (IEEE-488) and +5Vdc. Outputs will drive one TTL load. Inputs represent one TTL load. Mating connector supplied.

FRONT PANEL PROGRAMS

0	**Digital I/O**	Read or change state on digital I/O port.
1*	**Date Format**	Changes date display between MM.DD and DD.MM.
2*	**Settle Time**	Time to output CHANNEL READY pulse after closing relay.
3*	**IEEE Address**	Set bus address; cannot be programmed from bus.
4*	**Save Setup**	Stores present relay setup in numbered buffer.
5*	**Restore Setup**	Recalls relay setup.
6*	**Poles**	1-, 2-, or 4-pole configuration for scanning (1-pole requires 7056). 0-pole for matrixing.
7	**Alarm Time**	Set time for Alarm output pulse; repeats daily.
8	**Self Test**	Check RAM, ROM, LEDs.
90*	**Stand Alone**	Single configuration.
91*	**Master**	Daisy chain configuration.
92*	**Slave**	Daisy chain configuration.
93*	**Inspect**	Preview of relays to be closed (706 only).
94*	**Clear**	Clear buffer location (706 only).
99	**Reset**	Reset battery backup parameters to factory values.

*Battery backed up.

GENERAL

DISPLAY: Seven 0.5 in. LED digits with decimal point, function, and IEEE status annunciators.

INTERNAL CLOCK: Displays hour/minute/second or date/month; <1 minute/month error (typical).

BATTERY BACKUP: Rechargeable 3.6V NiCd. 1 month retention of data with unit turned off.

OPERATING ENVIRONMENT: 0°-50°C, 0%-80% relative humidity up to 35°C.

STORAGE ENVIRONMENT: −25° to 65°C.

CONNECTORS: Four BNC: External Trigger, Alarm Out/Serial In, Channel Ready, Serial Out (TTL compatible).

DIMENSIONS, WEIGHT: 705: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14½ in.). Net weight 3kg (6½ lbs.). **706:** 178mm high × 438mm wide × 448mm deep (7 in. × 17¼ in. × 7⅝ in.). Net weight 8.6kg (19 lbs.).

Selector Guide/Switching Cards

TYPE OF SWITCH	DESCRIPTION	KEY CHARACTERISTICS	PAGE
MATRIX			
7052	4×5 crosspoint expansion	3-pole switching (HI, LO, Guard)	77
THERMOCOUPLE			
7057A	Thermistor bridge reference	Isothermal block; J, K, T, R, S, B, E type thermocouples	78
7402	Semiconductor reference	Isothermal block; J, K, T, R, S, B, E type thermocouples	78
RELAY SWITCH			
7066	10 independent switches	2-pole N.O. or N.C. contacts	81
RF SCANNER			
7062	50Ω, unterminated	500MHz bandwidth	80
7063	50Ω, terminated	500MHz bandwidth	80
LOW VOLTAGE			
7059	10 channels	<1μV contact potential; 200V maximum	79
7064	20 channels	<1μV contact potential; 40V maximum	80
7057A	Thermocouple scanner	<1μV contact potential; 9 channels	78
7402	Thermocouple scanner	<1μV contact potential; 9 channels	78
7168	Nanovolt switching	<20nV differential contact potential; 8 channels	82
LOW CURRENT			
7058	Triax connector	<1pA offset current; 200V maximum	79
7158	BNC connector	<1pA offset current (current switching only)	82
GENERAL PURPOSE			
7056	10/20 channels	Quick disconnect	78
7052	4×5 matrix configuration	3-pole switching (HI, LO, Guard)	77
7059, 7064	Low voltage	Dry reed	79, 80
HIGH VOLTAGE			
7054	1000V	Single pole	77
HIGH CURRENT			
7053	5A	Power switching	77
HALL EFFECT			
7065	4 high impedance amplifiers	Switched Hall measurement outputs	83
4-WIRE SWITCHING			
7067	Kelvin connections	<1μV contact potential (sense)	81
UNIVERSAL			
7061	Relay driver	Troubleshooting extender, custom relay card	80

Switching Cards/**7052, 7053, 7054**

5×4 Matrix; High Current; High Voltage

Model 7052 5×4 Matrix Card is a general purpose switching card. The flexibility of matrix switching allows connection of any row to any column, singularly or in combination. Ideal for complex signal & measurement device switching, this matrix card can help minimize your need for custom cables and patch panels because the routings can be customized in software. Switched guards assure high isolation between channels.

CROSSPOINTS PER CARD: 5×4 configuration, 20 crosspoints.

CONTACT CONFIGURATION: 3-pole Form A; High, Low, and Guard.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 15mA per relay typical.

MAXIMUM SIGNAL LEVEL: 200V, 200mA, 10VA (resistive load only).

CONTACT LIFE: $>10^{8}$ closures cold switching; $>10^{6}$ closures at maximum signal levels.

CONTACT RESISTANCE: <1Ω to rated life.

CONTACT POTENTIAL: <20μV per contact pair input to output with copper leads.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}$Ω and <5pF.

INPUT ISOLATION:
Differential: $>10^{9}$Ω, <50pF.
Common Mode: $>10^{9}$Ω, <100pF.

COMMON MODE VOLTAGE: 200V peak.

CHANNEL CROSSTALK: >60dB into 50Ω @ 1MHz.

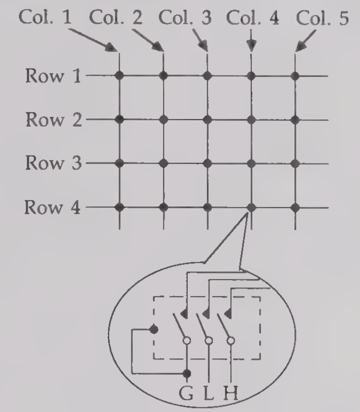
OFFSET CURRENT: <100pA.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.) Net weight 0.61kg (21.5 oz.).

7052 5×4 Matrix Card



Each cross point in the matrix consists of a 3-pole Form A (normally open) relay. Shield of each relay is connected to the column GUARD line.

Model 7053 High Current Scanner Card has 10 channels and features 5A contacts. The switching is designed to maintain current paths for signals not connected to the output, or, when internal jumpers are removed, to provide high input resistance for making voltage measurements. Semiconductor testing, materials research, power supply testing, solar cell measurements, electrochemical applications, and IC testing are among the applications simplified with the 7053 High Current Scanner Card.

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A with common Guard.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 80mA per relay typical.

MAXIMUM SIGNAL LEVEL: 300V, 5A, 100VA (resistive load only).

CONTACT LIFE: $>10^{7}$ closures cold switching; $>10^{5}$ closures at maximum signal levels.

CONTACT RESISTANCE: <0.15Ω to rated life.

CONTACT POTENTIAL: <1mV.

ACTUATION TIME: <15ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{9}$Ω, <50pF.

INPUT ISOLATION: $>10^{7}$Ω, <150pF.

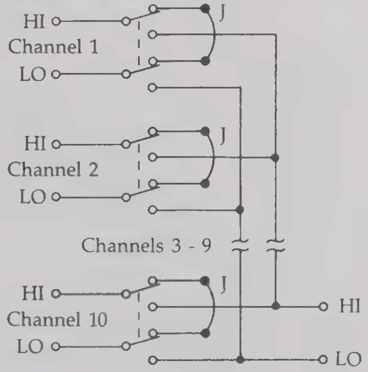
COMMON MODE VOLTAGE: 300V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.) Net weight 0.37kg (13 oz.).

7053 High Current Scanner Card



J = Removeable Jumper

Model 7054 High Voltage Scanner Card is a 10 channel high voltage scanner card. Voltages up to 1000V peak can be switched. LO is common to all channels and the output.

The high voltage switch can be used to selectively source voltages to any of ten circuits or to monitor voltages from as many sources. Applications include insulation resistance, breakdown, capacitor leakage, dielectric absorption, voltage coefficient, voltage stress tests, and monitoring of line voltages, motor voltages, and more.

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: Single pole Form A, common guard connection.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 50mA per relay typical.

MAXIMUM SIGNAL LEVEL: 1000V, 10mA, 10VA (resistive load only).

CONTACT LIFE: $>10^{8}$ closures cold switching; $>10^{6}$ closures at maximum signal levels.

CONTACT RESISTANCE: <1Ω.

ACTUATION TIME: <20ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}$Ω and <10pF.

INPUT ISOLATION: $>10^{9}$Ω and <150pF.

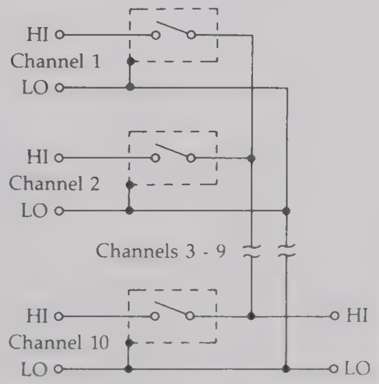
GUARD TO CHASSIS VOLTAGE: 200V maximum.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% noncondensing RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.28kg (10 oz.).

7054 High Voltage Scanner Card



7056, 7057A, 7402/Switching Cards

General Purpose; Thermocouple

Model 7056 General Purpose Scanner Card is a 10-channel scanner card with electrical connection made through the Model 7055 Quick Disconnect supplied. It is a cost-effective and versatile solution to relay switching applications. Each channel of the card has two Form A (SPNO) contacts. The switch may be wired for either 2-pole or 1-pole switching throught the selection of the appropriate output. In 1-pole operation, channels HI and LO operate as independent, isolated inputs, thereby effectively doubling the number of input channels.

CHANNELS PER CARD: 10 in 2-pole mode, 20 in 1-pole mode.

CONTACT CONFIGURATION: 2-pole Form A; includes Model 7055 Quick Disconnect Card. HI or LO switched to a separate output for 1-pole mode. Common guard connection.

CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size. Terminals mounted on 7055 Quick Disconnect portion of 7056.

RELAY DRIVE CURRENT: 24mA per relay typical.

MAXIMUM SIGNAL LEVEL: 150V, 250mA, 10VA (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^7$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <100µV per contact pair input to output with copper leads (<50µV typical).

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9$Ω, <20pF typical.

INPUT ISOLATION, DIFFERENTIAL: $>10^9$Ω, <50pF typical.

INPUT ISOLATION, COMMON MODE: $>10^9$Ω, <150pF typical.

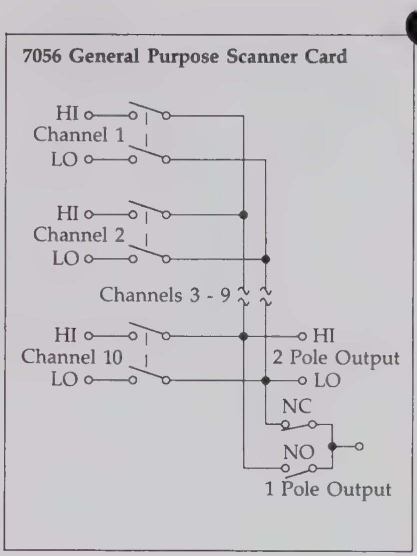
COMMON MODE VOLTAGE: 150V peak.

CHANNEL CROSSTALK: <50dB @ 1MHz into 50Ω load.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.27kg. (9.5 oz.).



Models 7057A and 7402 Thermocouple Scanner Cards' connections are made to copper screw terminals. This card permits monitoring of up to nine thermocouples or other transducers. The nine signal channels use a guarded 2-pole configuration.

An isothermal block provides electrical isolation up to 42V while assuring excellent thermal conductivity between cold junction terminations. A sensing device mounted in the isothermal block monitors the cold junction and outputs a calibrated reference voltage which is linearly related to the temperature. The Model 7057A provides a higher change in reference output for improved cold junction sensitivity.

Formulae for converting the voltage outputs of all of the most popular thermocouple types are included in the manual. The contact potential of <1µV per channel translates to <0.025°C error for precision measurements on type K thermocouples.

CHANNELS PER CARD: 9 plus temperature reference.

CONTACT CONFIGURATION: 2-pole Form A, with common guard.

CONNECTOR TYPE: Screw terminals in isothermal block, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 12mA per relay typical.

TEMPERATURE REFERENCE: Semiconductor, temperature dependent current source.

TEMPERATURE OFFSET: ±0.05°C maximum from HI to LO of any channel or between any two adjacent channels in one column on the isothermal block. ±0.1°C maximum between any two terminals on the isothermal block. Maximum additional dynamic offset due to 10°C step change in environment: ±0.1°C after one hour settling.

REFERENCE OUTPUT:
7057A: −1mV/°C (0mV at +30°C).
7402: +200µV/°C (+54.63mV at 0°C).

REFERENCE ACCURACY (1 YEAR): ±0.25°C (10°C to 35°C); ±0.5°C (0°C to 10°C and 35°C to 50°C).

WARMUP: 1 hour to rated accuracy in mainframe.

MAXIMUM SIGNAL LEVEL: 42V, 100mA, 2VA (resistive load only).

CONTACT POTENTIAL: <1µV.

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CHANNEL ISOLATION: $>10^8$Ω, <10pF.

INPUT ISOLATION: $>10^7$Ω, <150pF.

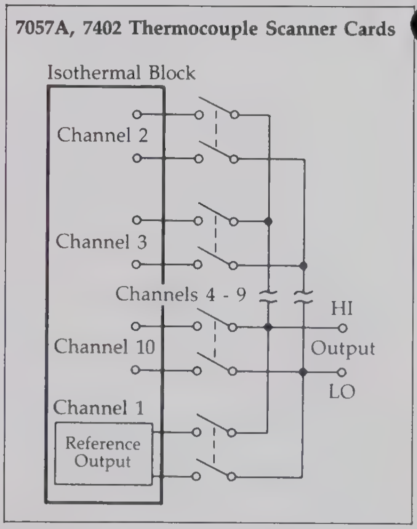
COMMON MODE VOLTAGE: 200V peak.

SPECIFIED ENVIRONMENT: 10° to 35°C, up to 70% RH.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in). Net weight 0.64kg (22.5 oz.).

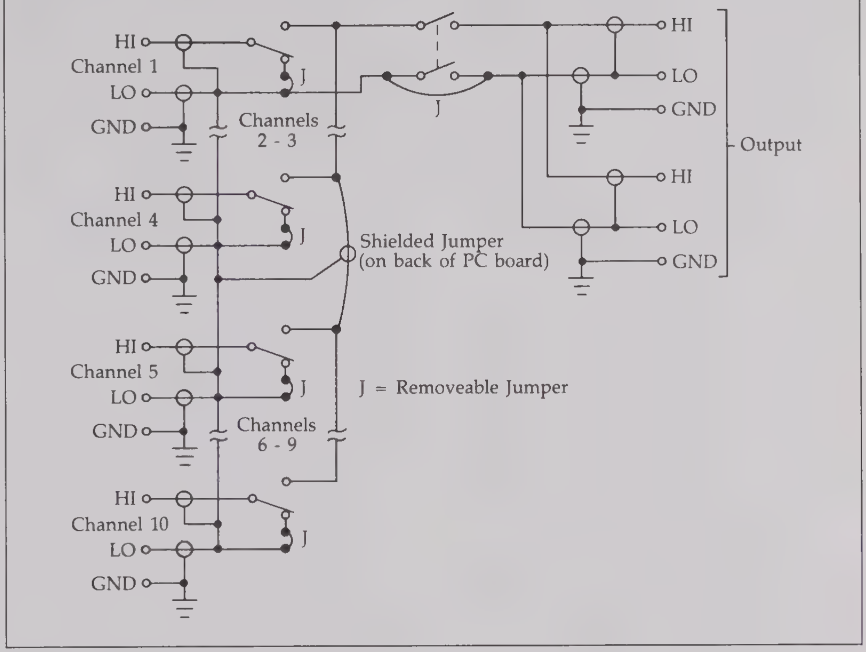


For optimum low level current switching up to 10 channels, the **Model 7058 Low Current Scanner Card** is designed to introduce minimal offset current error (under 1pA), while guarding ensures that high isolation ($10^{15}\Omega$) is maintained between input HI to input HI.

Removeable jumpers allow channels to be configured as voltage switches. Triaxial input connectors provide better shielding and permit direct connection to Keithley electrometers.

CHANNELS PER CARD: 10.
CONTACT CONFIGURATION: Single pole, break-before-make for signal HI input. Signal LO is common for all 10 channels. When a channel is off, signal HI is connected to signal LO through an internal removable jumper.
CONNECTOR TYPE: Triaxial.
RELAY DRIVE CURRENT: 24mA per relay typical.
MAXIMUM SIGNAL LEVEL: 200V, 100mA (resistive load only).
CONTACT LIFE: $>10^7$ closures cold switching; $>10^6$ closures at maximum signal levels.
CONTACT RESISTANCE: $<1\Omega$ to rated life.
CONTACT POTENTIAL: $<250\mu V$.
ACTUATION TIME: <15ms, exclusive of mainframe.
CHANNEL ISOLATION: $>10^{15}\Omega$, <0.1pF with internal jumper removed.
INPUT ISOLATION: $>10^{10}\Omega$, <50pF (Input HI to Input LO).

7058 Low Current Card



OFFSET CURRENT: $<10^{-12}$A ($<10^{-13}$A typical).
COMMON MODE VOLTAGE: <100V peak.
OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.
STORAGE ENVIRONMENT: −25°C to 65°C.

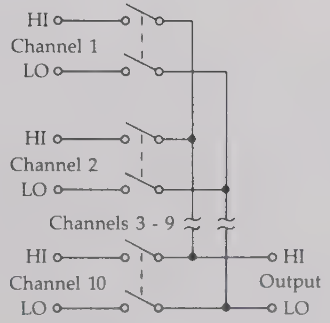
DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.54kg (19 oz.).
ACCESSORIES INCLUDED: Model 7024-3 Triaxial Cable, 0.9m (3 ft.).

For low level transducer switching, the **Model 7059 Low Voltage Scanner Card** is designed to reduce errors due to thermocouple effects in the contacts ($<1\mu V$ maximum) and ensure that high isolation ($10^{12}\Omega$) is maintained between input signals. It will switch any one of ten signals to one output, or switch one signal to any one of ten outputs. Switch settling time is less than 2 milliseconds.

CHANNELS PER CARD: 10.
CONTACT CONFIGURATION: 2-pole Form A, common guard connection.
CONNECTOR TYPE: Screw terminal, #18 AWG maximum wire size.
RELAY DRIVE CURRENT: 13mA per relay typical.
MAXIMUM SIGNAL LEVEL: 200V, 100mA, or 2VA (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.
CONTACT RESISTANCE: $<2\Omega$ to rated life.
CONTACT POTENTIAL: $<1\mu V$ input to output with copper leads (<200nV typical within 1 minute of actuation).
WARM UP: 1 hour in mainframe for thermal stability.
ACTUATION TIME: <2ms, exclusive of mainframe.
CHANNEL ISOLATION: $>10^{12}\Omega$, <10pF.
INPUT ISOLATION, DIFFERENTIAL: $>10^9\Omega$, <50pF.
INPUT ISOLATION, COMMON MODE: $>10^9\Omega$, <150pF.
COMMON MODE VOLTAGE: <200V peak.
OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.
STORAGE ENVIRONMENT: −25°C to 65°C.
DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.35kg (12½ oz.).

7059 Low Voltage Card



7061, 7062, 7063, 7064/Switching Cards

Universal Adapter; RF Switches; 20-Channel Low Voltage

Model 7061 Universal Adapter Card was designed with a 6-volt supply, ground trace, and a grid pattern of plated-through holes on 0.1-in. centers for mounting special relays or circuits. Relay drive lines from the scanner mainframe can be used for control. A supplied ribbon cable assembly extends the relay drive lines beyond the enclosure for easy access to relay cards for troubleshooting.

SUPPLY SPECIFICATIONS: 705 mainframe: 6V, 350mA max; 706 mainframe: 6V, 4A max.

RELAY DRIVE LINES: 350mA sink.

HARDWARE SPACE: $^{15}/_{16}$ in., maximum height a component can protrude from the universal adapter card and fit in the 705 or 706 mainframe.

HOLE SIZE: 0.062 diameter.

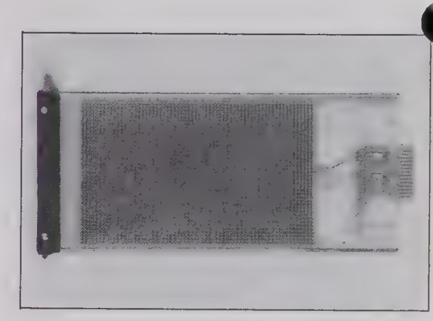
HOLE SPACING: 0.1 centers

RIBBON CABLE: 2 ft. length with connectors preassambled.

STRAIN RELIEF CLAMP: Assembly provided.

OPERATING CODES: Provided in manual.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.17kg (6 oz.).



RF Switch Cards have two independent 1 of 5 switches. Each switch has a separate through connection which can be used to cascade sections to achieve larger scanning configurations in multiples of 5. The switched transmission line design maintains the 50Ω characteristic through the switch, minimizing reflection and loss. This approach results in reduced capacitance and better frequency response. The Model 7063 inputs are terminated in the 50Ω characteristic impedance when not selected.

A 500MHz bandwidth assures signal integrity over a broad range from dc to communications signals and digital waveforms. Coaxial switching provides additional shielding and noise immunity in the system environment.

SWITCHES PER CARD: 2 (with isolated grounds).

CHANNELS PER SWITCH: 5.

SWITCH CONFIGURATION: 1-pole, 5 throw.

EXPANSION: A through connector is provided for cascading switches.

CONNECTOR TYPE: BNC.

RELAY DRIVE CURRENT: 100mA per relay typical.

ACTUATION TIME: 10ms exclusive of mainframe.

RELEASE TIME: 5ms.

CHARACTERISTIC IMPEDANCE: 50Ω.

TERMINATIONS: Model 7062, none; Model 7063, 50Ω on unselected inputs.

PROPAGATION DELAY: <2ns.

INSERTION LOSS: <0.1dB below 20MHz, <1.0dB below 250MHz, and <3.0dB below 500MHz.

ISOLATION CHANNEL: (switch to channel): >75dB below 20MHz, >55dB below 250MHz, and >60dB below 500MHz.

ISOLATION (switch to switch): >80dB below 20MHz, >70dB below 250MHz, and >60dB below 500MHz.

MAXIMUM SIGNAL LEVEL: 24V on Model 7062, 5V on Model 7063, switched; 50mA; 0.5 watt switched.

CONTACT LIFE: $>10^6$ closures cold switching; $>10^5$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω input to output.

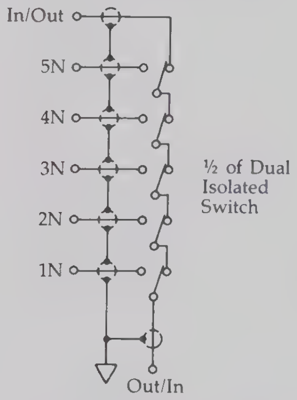
CONTACT POTENTIAL: <20μV.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.54kg (1 lb. 3 oz.).

7062 (50Ω unterminated) & 7063 (50Ω terminated) RF Switch Cards



Unselected inputs are terminated in 50Ω on Model 7063.

Model 7064 20-Channel Low Voltage Scanner Card has 20 channels and features <1μV thermal offset. It will switch any one of twenty signals to one output, or switch one signal to any one of twenty outputs. Switching is accomplished in less than 2 milliseconds. Expected relay life (10^8 closures) is obtained when signals less than 10V or 10mA are switched.

CHANNELS PER CARD: 20.

CONTACT CONFIGURATION: 2-pole Form A, common guard connection.

CONNECTOR TYPE: Screw terminal #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 14mA per relay typical.

MAXIMUM SIGNAL LEVEL: 40V, 100mA, or 2VA (resistive load only).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^5$ closures at maximum signal levels.

CONTACT RESISTANCE: <2Ω to rated life.

CONTACT POTENTIAL: <1μV differential voltage, input to output with copper leads (<200nV typical within 1 minute of actuation).

WARM UP: 1 hour in mainframe for thermal stability.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^{12}$, <10pF.

INPUT ISOLATION, DIFFERENTIAL: $>10^9$Ω, <75pF.

INPUT ISOLATION, COMMON MODE: $>10^9$Ω, <150pF.

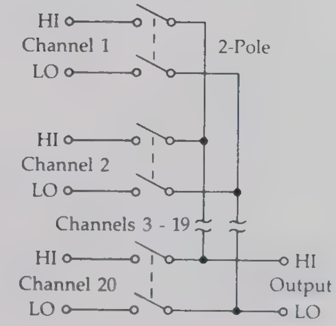
COMMON MODE VOLTAGE: <100V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.54kg (1 lb. 3 oz.).

7064 20-Channel Low Voltage Card



Model 7066 Relay Switch Card is a non-multiplexed switching card with ten independent and isolated channels. Each channel switches 2-pole Form A relays and can be user changed for either Form B or Form C configuration using movable jumpers. The switch specifications are well suited for applications such as power line switching, controlling external circuits and devices, and switching signals where multiplexing is not desired. Each channel is terminated with a screw terminal block which "quick disconnects" from the card.

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 2-pole Form A, common ground connection.

CONNECTOR TYPE: Quick disconnect block for each channel. Screw terminals accept #14-#26 AWG wire.

RELAY DRIVE CURRENT: 80mA per relay typical.

MAXIMUM SIGNAL LEVEL: 250V dc or rms, 350V peak switched, 2A dc or rms, 60W dc or rms. 60W dc, 125VA ac (resistive load).

CONTACT LIFE: $>10^8$ closures cold switching; $>10^5$ closures at maximum ratings.

CONTACT RESISTANCE: <0.1Ω initial, <2Ω rated life.

CONTACT POTENTIAL: <30µV per contact pair input to output with copper leads (<10µV typical).

ACTUATION TIME: <10ms, exclusive of mainframe.

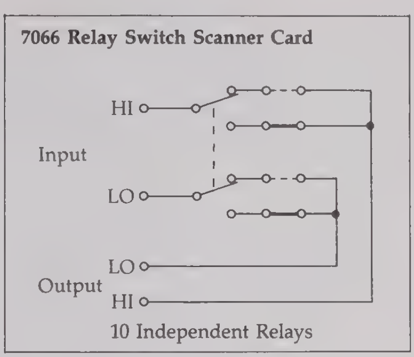
CHANNEL ISOLATION: $>10^9$Ω.

INPUT ISOLATION: $>10^9$Ω.

COMMON MODE VOLTAGE: 350V peak.

OPERATING ENVIRONMENT: –25° to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 227mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.28kg (10 oz.).


7066 Relay Switch Scanner Card

4-wire or Kelvin connections are generally made to minimize errors created by I-R drops in the cabling and interconnects of a test system. Each channel of the **Model 7067 4-Wire Scanner Card** has two general purpose source contacts that switch currents up to 350mA, as well as two high quality contacts (<1µV contact potential) for dry switching of voltage to the sensing circuit.

The 7067 is well suited to precision resistance measurements as required in temperature coefficient testing. Other applications include remote sensing of voltage source outputs and bridge measurements.

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: 4-pole Form A, common shield connection.

CONNECTOR TYPE: Quick disconnect screw terminal, #18 AWG maximum wire size.

RELAY DRIVE CURRENT: 40mA per channel typical.

SENSE LINES:
- **Maximum Signal Level:** 150V, 100mA, 2VA (resistive loads only).
- **Contact Resistance:** <0.5Ω initial, 2Ω to rated life.
- **Contact Potential:** <1µV per contact pair.

SOURCE LINES:
- **Maximum Signal Level:** 150V, 350mA, 10VA (resistive loads only).
- **Contact Resistance:** <0.2Ω initial, 2Ω to rated life.
- **Contact Potential:** <50µV per contact pair.

CONTACT LIFE: $>10^8$ closures cold switching; $>10^6$ closures at maximum signal levels.

WARMUP: 1 hour for thermal stability.

ACTUATION TIME: <2ms, exclusive of mainframe.

CHANNEL ISOLATION: $>10^9$Ω, <10pF.

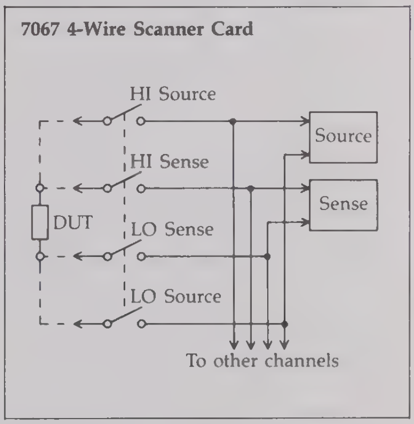
INPUT ISOLATION, DIFFERENTIAL: $>10^9$Ω, <50pF.

INPUT ISOLATION, COMMON MODE: $>10^9$Ω, <100pF.

COMMON MODE VOLTAGE: <150V peak.

OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: –25°C to 65°C.


7067 4-Wire Scanner Card

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.4kg (14 oz.).

APPLICATIONS: 4-wire resistance (resistors, relays, connectors, switches, RTDs). External sensing on voltage sources. DUT in/out switching (potentiometers, isolation amplifiers, strain gages).

7158, 7168/Switching Cards

Low Current; Nanovolt

The **Model 7158 Low Current Scanner Card** provides quality low current switching at an affordable price. The offset current error generated is specified <1pA, with typical performance at <10fA.

When used with a voltage source and electrometer or picoammeter, this card can easily automate insulation resistance tests, reverse leakage tests on semiconductor junctions, or gate leakage tests on FETs.

The Model 7158 is designed to maintain the current path even when the channel is de-selected. Input connectors are BNC for shielding of the sensitive measurements and for compatibility with low noise coaxial cables such as Keithley accessory cable Models 4801 and 4803. Two outputs are provided to allow for chaining of several scanner cards to one measurement instrument, and an isolation relay in the output HI minimizes interaction between cards.

CHANNELS PER CARD: 10.

CONTACT CONFIGURATION: Single pole. Signal LO is common for all 10 channels and output. When a channel is off, signal HI is connected to signal LO.

CONNECTOR TYPE: BNC.

RELAY DRIVE CURRENT: 100mA per card typical.

MAXIMUM SIGNAL LEVEL: 100mA, 30V compliance (resistive load only).

CONTACT LIFE: $>10^7$ closures cold switching; $>10^6$ closures at maximum signal levels.

CONTACT RESISTANCE: <1Ω.

CONTACT POTENTIAL: <200μV.

ACTUATION TIME: <1ms, exclusive of mainframe.

OFFSET CURRENT: $<10^{-12}$A ($<10^{-14}$A typical).

COMMON MODE VOLTAGE: <30V maximum.

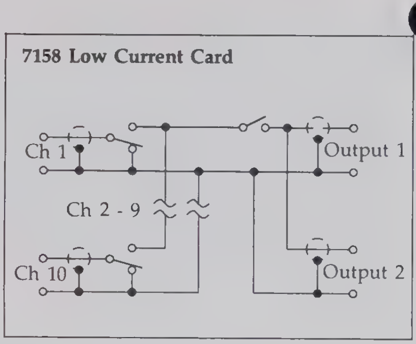
OPERATING ENVIRONMENT: 0° to 50°C, up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25°C to 65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.54kg (19 oz.).

ACCESSORY SUPPLIED: Model 4801 Low Noise Cable.

ACCESSORY AVAILABLE: Model 4804 Female Triaxial to Male BNC Adapter.



Model 7168 Nanovolt Scanner Card is an eight-channel, two-pole card with <20nV of thermal offset. It will switch any one of eight signals to one output in less than 3ms. Channel offset leakage current is <50pA at 23°C.

Keithley also offers the Package 68, which includes the 7168 Nanovolt Scanner Card, Model 705 20-Channel Scanner mainframe, and Model 181 Digital Nanovoltmeter. When the 7168 is used with the Model 181, the noise and drift performance of the 181 is not degraded.

CHANNELS PER CARD: 8.

CONFIGURATION: Two poles per channel, input HI and LO.

CONNECTOR TYPE: Screw terminal to bare copper printed circuit pad.

MAXIMUM SIGNAL LEVEL: 10V, 50mA peak (resistive load only).

CONTACT RESISTANCE: <12Ω.

CONTACT POTENTIAL: <20nV between channels.

OFFSET CURRENT: <50pA at 23°C.

CONTACT TYPE: Solid state JFET switch.

ACTUATION TIME: <3ms, exclusive of mainframe.

INPUT ISOLATION: $>10^9$Ω, <40pF between any input terminals or between any input terminal and earth.

COMMON MODE VOLTAGE: 30V peak.

MAXIMUM VOLTAGE BETWEEN ANY TWO TERMINALS: 10V.

WARMUP: 2 hours in mainframe for thermal stability.

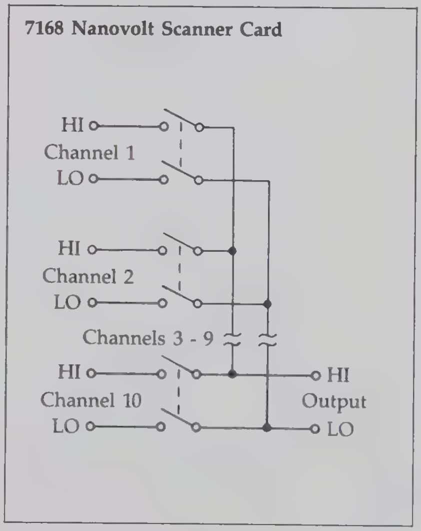
OPERATING ENVIRONMENT: 0° to 40°C; up to 35°C at 70% RH.

STORAGE ENVIRONMENT: −25° to 60°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼ in. × 4½ in. × 10¾ in.). Net weight 0.53kg (18.5 oz.).

ACCESSORIES SUPPLIED: Model 7168-316 Input Cable (8 supplied); Model 1507 Low Thermal Input Cable.

ACCESSORIES AVAILABLE: Model 1483 Low Thermal Connection Kit.



Model 7065 Hall Effect Card

Keithley provides a family of Hall voltage and resistivity measurement products, from a single Model 7065 Hall Effect Card—designed to be used with our Model 705 and 706 Scanners—to the System 110 provided by our Systems Division.

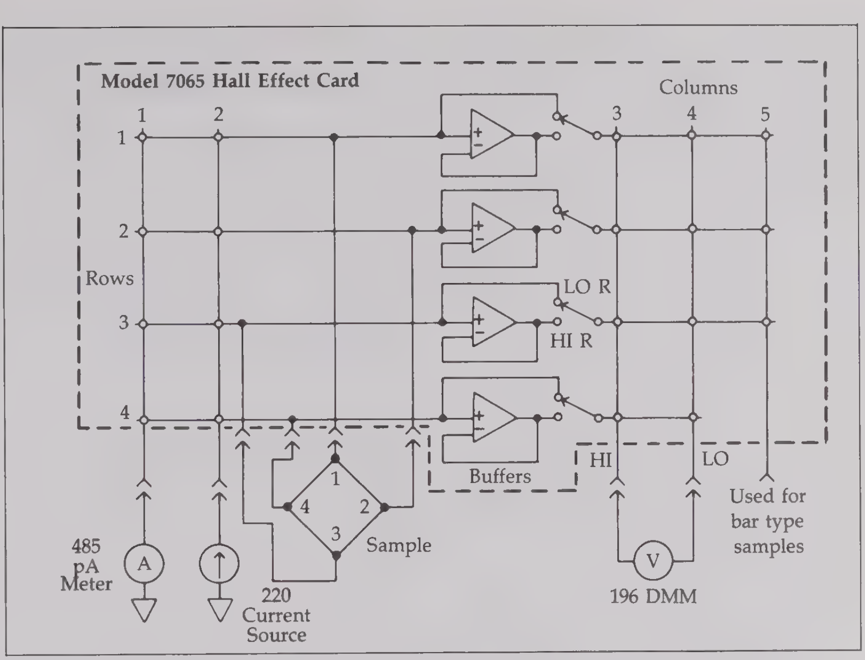
The Model 7065 Hall Effect Card has been designed for those interested in assembling their own Hall test systems. The 7065 is a signal conditioning card designed to buffer test signals from the Hall sample to the measurement instrumentation, and to switch current from a source to the Hall sample. Designed to be used with either our 705 or 706 scanner mainframe, the 7065 provides the capability to measure Hall voltages as low as 50nV and sample resistances to $10^{12}\Omega$.

Connections are simplified by including accessories to interface sample, scanner, instruments, and controller. The 7065 can be connected directly to the sample, and all instruments can be connected to the IEEE-488 bus for interfacing to the controller.

The Model 7065 can be purchased separately or with a Model 705 scanner mainframe. Keithley also offers the Hall Effect Package 80, a complete package of instruments and accessories including:

- Model 705 Scanner Mainframe (page 74)
- Model 7065 Hall Effect Card, including accessories
- Model 196 Programmable DMM (page 16)
- Model 220 Programmable Current Source (page 65)
- Model 485/4853 Picoammeter with IEEE-488 Interface (page 46)
- Model 7008-3 IEEE-488 Cable (3 supplied) (page 95)

The Model 7065 can be operated in either a low resistivity or a high resistivity mode. Input voltage ranges in both operating modes is +8V to −8V. In the high resistivity mode, input impedance is greater than 100TΩ, input bias current is less than 150fA, and output resistance is less than 60Ω.



Specifications/Model 7065 Hall Effect Card

CONFIGURATION

Input characteristics and output matrix configurable for van der Pauw or Hall bar measurements. Input characteristics selectable for either low resistivity or high resistivity samples.

LOW RESISTIVITY MODE

Input Voltage Operating Range: +8V to −8V.

Input Impedance: >10GΩ in parallel with <420pF.

Input Bias Current: <100pA.

Input Voltage Noise: <50nV p-p, 0.1 to 10Hz bandwidth.

Input to Output Resistance: <30Ω.

HIGH RESISTIVITY MODE

Input Voltage Operating Range: +8V to −8V.

Input Impedance: >100TΩ in parallel with < 3pF.

Input Bias Current: <150fA at 23°C. Doubles approximately every 10°C rise in ambient room temperature.

Input Voltage Noise: <10μV p-p, 0.1 to 10Hz bandwidth.

Output Resistance: <60Ω.

GENERAL

CONNECTORS:

Current Source Input: Two-lug female triaxial. Input HI to LO clamped at ±12V. Maximum Input: 100mA.

Sample Inputs: Four two-lug female triaxial. Outer shell is analog ground. Inner shield is driven guard. Maximum Input Overload (HI to analog ground or GUARD to analog ground): ±12V.

Current Monitor Output: Insulated female BNC.

Measurement Outputs: Spring-loaded terminals. Accepts AWG. #18 to #24 wire. Maximum Load: 1mA.

MAXIMUM COMMON MODE VOLTAGE (analog ground to earth ground): 30V peak, dc to 60Hz sine wave.

ISOLATION: Analog ground to earth ground: $>10^9\Omega$ in parallel with 150pF.

WARMUP: 1 hour to rated specifications.

ENVIRONMENT: Operating: 0°-35°C, up to 70% R.H. Storage: −25° to +65°C.

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1 in. × 4 in. × 10 in.). Net weight: 434kg (15.5 oz.).

ACCESSORIES SUPPLIED:

Model 4801:	Low Noise Input Cable
Model 6167:	Guarded Input Adapter
Model 7024-3:	Triaxial Cable (3 ft.)
Model 7024-10:	Triaxial Cable (10 ft.)
Model 4802-10:	Low Noise Input Cable (10 ft.)
Model 7025-10:	Triaxial Input Cable (10 ft.) (5 supplied)
Model 7008-6:	IEEE-488 Cable (6 ft.)
Model 4851:	BNC Shorting Plug
Model SC-72-0:	Single Conductor Insulated Wire, black (4 ft.) (2 supplied)
Model SC-72-9:	Single Conductor Insulated Wire, white (4 ft.)
Model BG-5:	Single Banana Plug, black (2 supplied)
Model BG-10-1:	Single Banana Plug, white
Model BG-7:	Double Banana Plug, black
Model SC-8:	2-Conductor Cable w/shield (10 ft.)

All specifications are 1 year, 18°-28°C, installed in scanner mainframe.

IEEE-488 Interfaces

For IBM-PC/XT/AT and Compatibles

From Capital Equipment Corporation

PC-488-CEC Speaks Your Language. PC-488-CEC supports all of the popular programming languages including interpreted and compiled BASIC, TBASIC™, Microsoft® Pascal, Turbo® Pascal, Microsoft® C, Lattice™C, DeSmet™C, Microsoft® FORTRAN, and assembly language.

PC-488-CEC is Ready to Run. To improve your productivity, PC-488-CEC software is packaged in read-only memory. This means the entire system is ready to run as soon as you turn on the power.

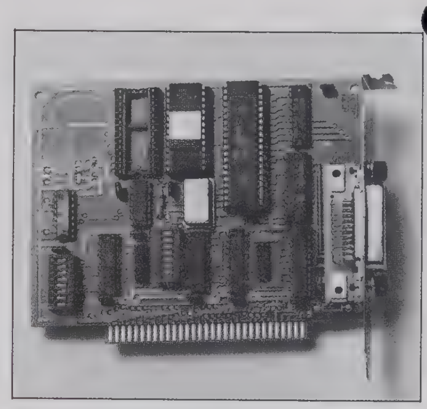
Computers. PC-488-CEC will work with the IBM-PC/XT/AT, AT&T 6300, Compaq, Sperry, Tandy, TI, Zenith, and other IBM-PC compatibles.

Commands. Supports all IEEE-488 commands. Listen, talk, device clear, group execute trigger, go to local, interface clear, local lockout, parallel poll configure/disable, remote enable, selected device clear, serial poll enable/disable, pass control, take control, unlisten, untalk.

Direct Memory Access. Transmit and receive up to 64K byte arrays at over 800K bytes/second. Select from single, demand, or burst DMA in either background or foreground modes.

Serial and Parallel Polling. High-level commands support all polling functions.

Order: PC-488-CEC IEEE-488 Interface Card



Software Products

Co-Operator™

Co-Operator Writes Programs For You.

Co-Operator Will Save You Time. Think of Co-Operator as your assistant in GPIB control programming. Co-Operator presents you with all the choices, and visually leads you through the control sequence. Then, at a touch of the **write code** key, Co-Operator produces a fully commented BASIC program.

Co-Operator is Flexible. Some "easy-to-use" software is simple because it limits what you can do. Co-Operator gives you the full power of the industry standard IEEE-488 interface.

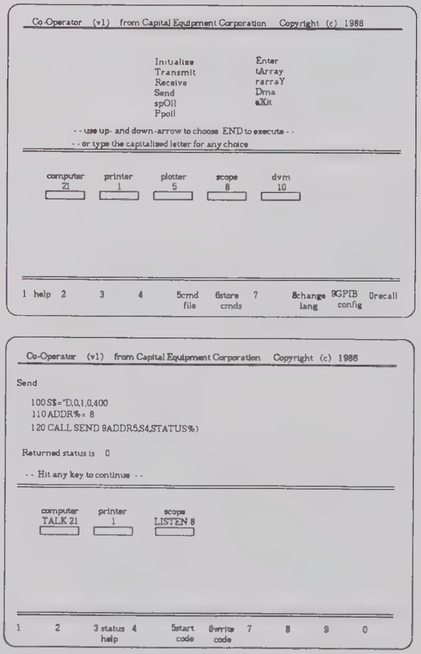
The Perfect Partner for PC-488-CEC. Co-Operator works with the PC-488-CEC interface card to make your job easier.

Features:

- Interactive GPIB control
- Automatic BASIC program generation
- Record and play back commands
- Coding examples for all PC-488-CEC programming languages
- Device status shown on screen
- Extensive help screens

(PC-488-CEC interface card required)

Order: PC-488-COP Co-Operator Software



```
Co-Operator   (v1)   from Capital Equipment Corporation   Copyright (c) 1986

                    Initialize          Enter
                    Transmit            tArray
                    Receive             rarraY
                    Send                Dma
                    spOll               eXit
                    Ppoll

         - - use up- and down-arrow to choose  END to execute - -
         - - or type the capitalised letter for any choice

   computer   printer   plotter   scope   dvm
      21         1         5        8      10

1 help  2     3     4      5cmd   6store  7     8change 9GPIB   0recall
                           file    cmds          lang    config
```

```
Co-Operator   (v1)   from Capital Equipment Corporation   Copyright (c) 1986

Send

   100 S$="D,0,1,0,400
   110 ADDR% = 8
   120 CALL SEND 9ADDR5,S4,STATUS%)

 Returned status is   0

  - - Hit any key to continue - -

   computer   printer    scope
   TALK 21       1      LISTEN 8

1       2      3 status 4     5start  6write  7     8     9     0
                 help          code    code
```

Co-Operator Screens

BASIC Interrupt Software

Now you can have all of the power of a dedicated GPIB controller at a small fraction of the price.

When used with the PC-488-CEC (above), PC-488-INT BASIC Interrupt Software gives you all these features:

- BASIC subroutine processing of any GPIB interrupt
- BASIC statements to enable and disable GPIB interrupts
- BASIC functions to determine GPIB interrupt status
- The ability to log and selectively execute interrupts
- Programmable interrupt line selection
- Compatibility with all other interrupt functions (timer, keyboard, disk, and I/O)

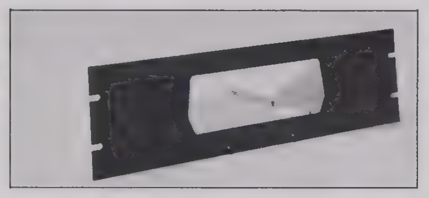
PC-488-INT Interrupt Software is easy to learn, easy to use, and powerful.

Order: PC-488-INT Interrupt Software

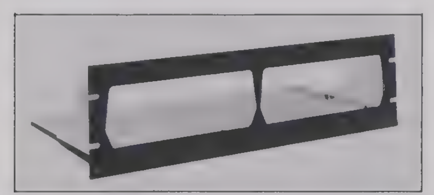
Rack Mount Kit Selector Guide; 1010 - 1019S-2

Keithley rack mounting kits contain instructions and all hardware necessary for mounting many Keithley products in a standard 19 in. system cabinet such as Keithley's Model 8000. Described here are the wide range of kits available and the various instruments that fit each kit. Shelf-type racks include a base plate for the mounted instrument(s); other kits are side-mounted and attach the instrument to the side of the rack. Dimensions shown are for the assembled kit and, unless otherwise noted, do not include dimensions of mounted instruments.

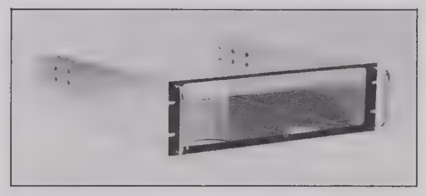
INSTRUMENT MODEL NUMBER	SINGLE		DUAL		TYPE OF MOUNT
	FIXED	SLIDE	FIXED	SLIDE	
169, 175, 177, 179A	1010		1017		Shelf
181	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
193A, 194A	1938	1939			Bracket w/handles
195A, 196	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
197	1010		1017		Shelf
220, 224, 230	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
228	2288A	2289A			Bracket w/handles
261	4003A				Side
427	2000				Side
480, 485, 580	1010		1017		Shelf
590	2288A	2289A			Bracket w/handles
595, 614, 617	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
619	1019A	1019S			Shelf
642	2000				Side
705, 740, 775A	1019A-1	1019S-1	1019A-2	1019S-2	Bracket w/handles
706	7068	7069			Bracket w/handles
26000	4003A				Side



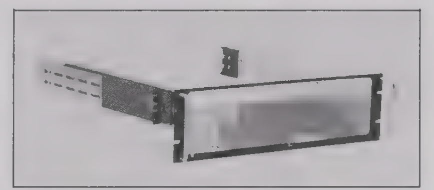
Model 1010 is a shelf-type kit for mounting a single Keithley Model 169, 175, 177, 179A, 197, 480, 485, or 580. **Dimensions:** 132mm high × 483mm wide × 254mm deep (5.2 in. × 19 in. × 10 in.).



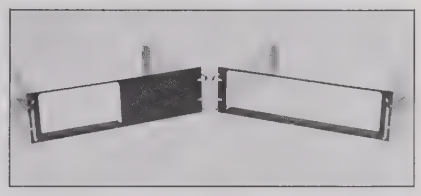
Model 1017 is similar to Model 1010 but mounts any two Models 169, 175, 177, 179A, 197, 480, 485, and 580. **Dimensions:** Same as Model 1010.



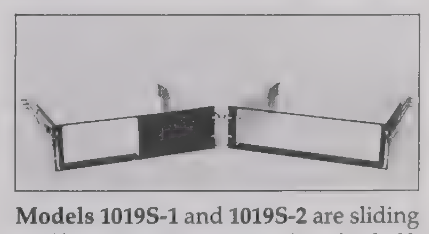
Model 1019A is a fixed shelf-type rack mounting kit for Model 619. **Dimensions:** 132mm high × 483mm wide × 442mm deep (5.2 in. × 19 in. × 17.4 in.)



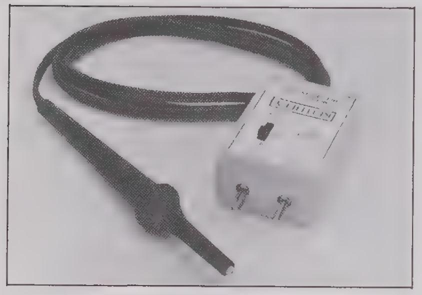
Model 1019S is a sliding shelf-type rack mounting kit for Model 619. **Dimensions:** 132mm high × 483mm wide × 508mm deep (closed), 1041mm deep (open) [5.2 in. × 19 in. × 20in. (closed), 41 in. (open)].



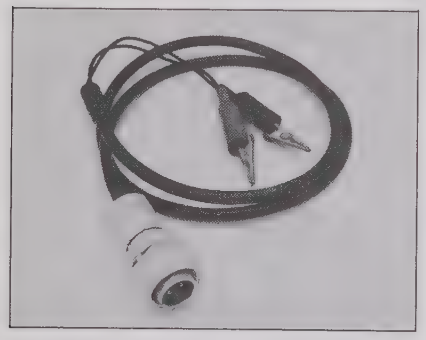
Models 1019A-1 and **1019A-2** are fixed shelf-type rack mounting kits for half-rack, 127mm (5½ in.) high instruments (see Selector Guide above). The 1019A-1 kit mounts one instrument and the 1019A-2 kit mounts two. **Dimensions:** 132mm high × 483mm wide × 356mm deep (5¼ in. × 19 in. × 14 in.).



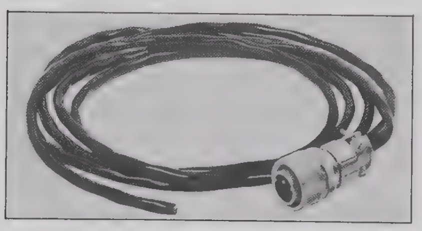
Models 1019S-1 and **1019S-2** are sliding shelf-type rack mounting kits for half-rack, 127mm (5½ in.) high instruments (see Selector Guide above). The 1019S-1 kit mounts one instrument and the 1019S-2 kit mounts two. **Dimensions:** 132mm high × 483mm wide × 356mm deep (5¼ in. × 19 in. × 14 in.).



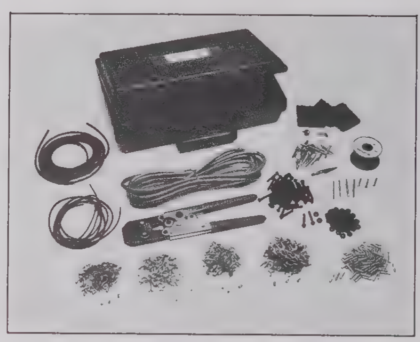
Model 1301 Temperature Probe
Range: −55°C to 150°C.
Output: 1mV/°C; compatible with any DMM with ≥10MΩ input impedance.
Accuracy: ±2°C from 0° to 100°C; ±3°C from −55° to 0°C and 100° to 150°C.
Power: 9V alkaline or C-Zn (NEDA 1604) battery; 500 hr. battery life.



Model 1481 Low Thermal Input Cable: 1.2m (4 ft.) of coaxial cable terminated on one end with Model 1486 (mating connector to Models 148 and 181) and two alligator clips on the other. Useful for making the best temporary connections in low voltage circuits.

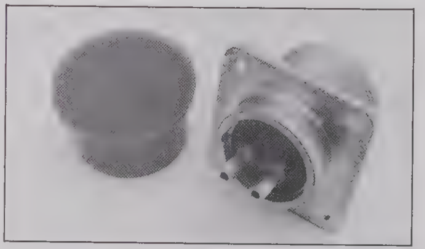


Model 1482 Low Thermal Input Cable: Similar to Model 1481; 3m (10 ft.) of cable terminated with a mating connector and bare copper leads, allowing special low thermal input connectors to Models 148 and 181.

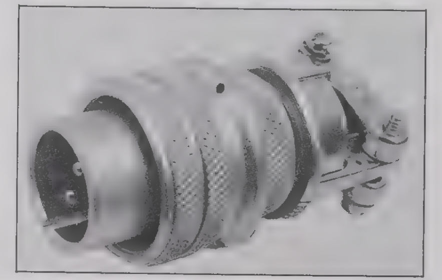


Model 1483 Low Thermal Connection Kit: Contains crimp tool, pure copper lugs, alligator clips, and assorted hardware.

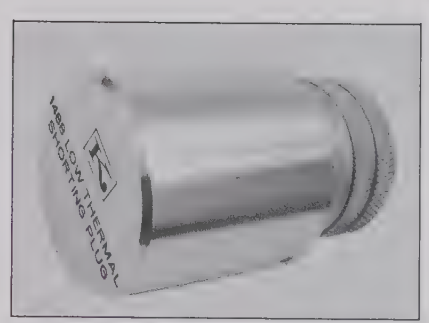
Model 1484 Refill Kit: Replacement parts for 1483 kit, including lugs, clips, and hardware.



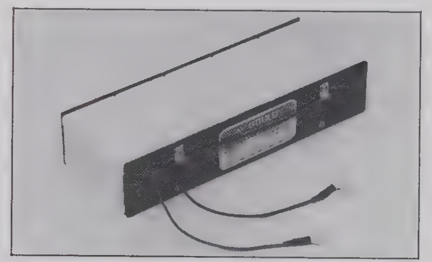
Model 1485 Female Low Thermal Input Connector: For Models 148 and 181.



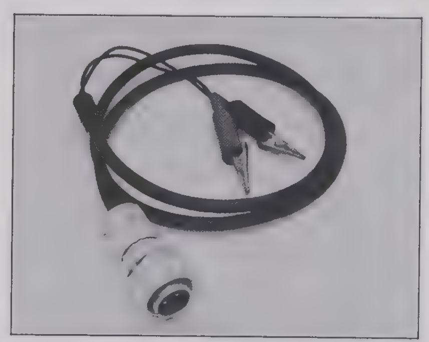
Model 1486 Male Low Thermal Connector: Mates with the input connector for Models 148 and 181. Allows the user to make a custom length input cable.



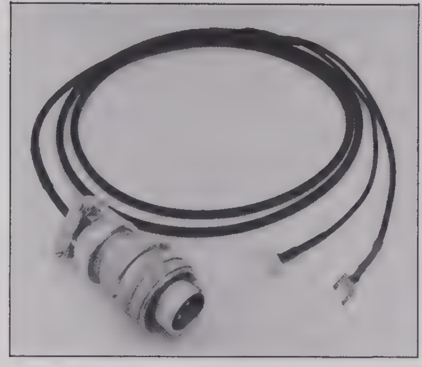
Model 1488 Low Thermal Shorting Plug: For checking proper operation and for calibrating Models 148 and 181. Special construction minimizes errors caused by thermal EMF.



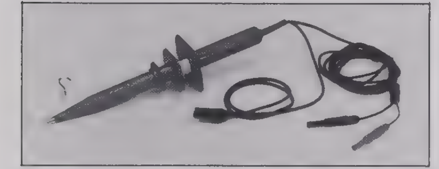
Model 1489 Battery Pack: Replacement nickel-cadmium 6V battery pack for Model 148. 14 hours full charge to complete discharge. The battery lasts about 1000 rechargeable cycles.



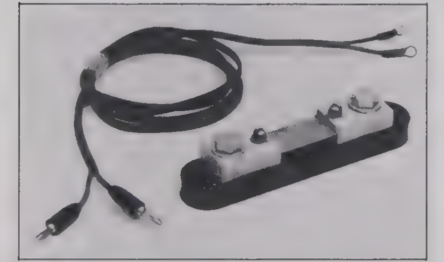
Model 1506 Low Thermal Input Cable: 1.2m (4 ft.) triaxial cable with low thermal mating connector to Model 181 on one end and two copper alligator clips on the other.



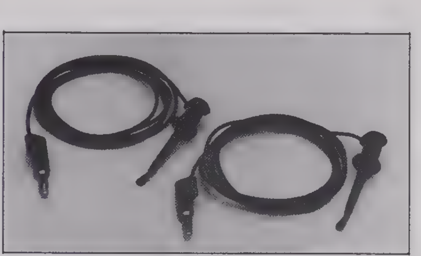
Model 1507: Similar to Model 1506; terminated with copper spade lugs.



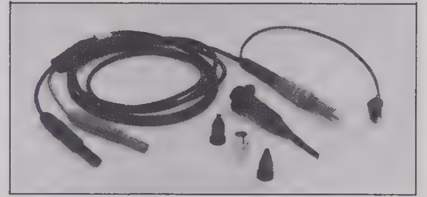
Model 1600A High Voltage Probe (DMMs)
Maximum Input: 40kV dc or peak ac to 300Hz.
Input Resistance: 1000MΩ.
Division Ratio: 1000:1 (into 10MΩ).
Ratio Accuracy (into 10MΩ DMM): ±2.5% from 1kV to 40kV dc; −3dB at 300Hz ac.
Operating Temperature: 0° to 50°C.
Cable Length: 2m (6.6 ft.).



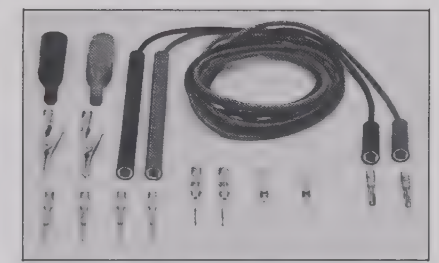
Model 1651 50-Ampere Shunt: External 0.001Ω ±1%, 4-terminal shunt; extends current measuring capability of Keithley DMMs to 50A.
Cable Length: 1.4m (56 in.).



Model 1681 Clip-On Test Lead Set: Two 1.2m (48 in.) leads terminated with banana plugs and spring-action clip-on probes.



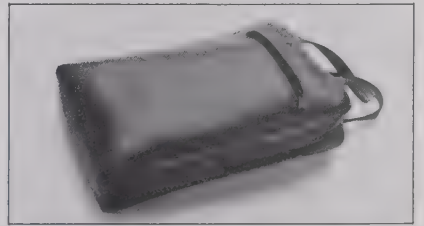
Model 1682A RF Probe (DMMs)
AC to DC Transfer Accuracy: ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in rms of a sine wave; compatible with instruments with 10MΩ input resistance.
Voltage Range: 0.25V to 15V rms.
Maximum Allowable Input: 50V ac peak, 200V (ac+dc) peak.
Cable Length: 1.5m (59 in.).



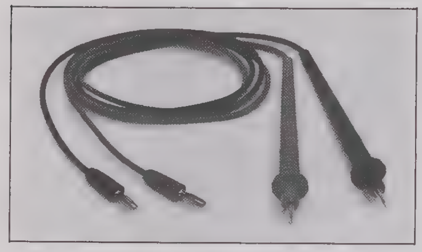
Model 1683 Universal Test Lead Kit: 14 piece test lead kit with interchangeable plug-in accessories. 2 flexible test leads, 1.2m (4 ft.), 1 red, 1 black; 2 alligator clips with boots, 1 red, 1 black; 2 banana plugs; 2 needle tips with chucks; 2 spade lugs; 4 heavy duty tip plugs.

Model 1684 Hard Shell Carrying Case: Hard vinyl case, 100mm × 330mm × 356mm (4 in. × 13 in. × 14 in.) has fitted foam insert with room for bench-size instrument, instruction book, and small accessories.

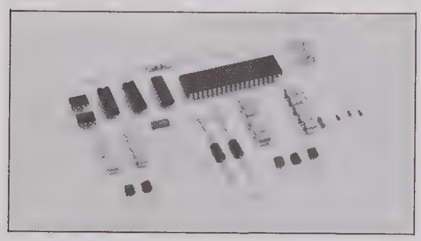
Model 1685 Clamp-On AC Probe: Measures ac current by clamping onto a single conductor. Interruption of the circuit under test is unnecessary. The Model 1685 detects current by sensing the changing magnetic field produced by the current flow.
Ranges: 2, 20, and 200A rms.
Accuracy: ±4% of range at 60Hz; ±6% of range at 50Hz.
Temperature Coefficient: ±0.05%/°C on 20A and 200A ranges; ±0.3%/°C on 2A range.
Max. Allowable Current: 300A rms.
Max. Conductor Voltage: 600V rms.
Conversion Ratio: 0.1V ac/A rms.
Cable Length: 3m (10 ft.).



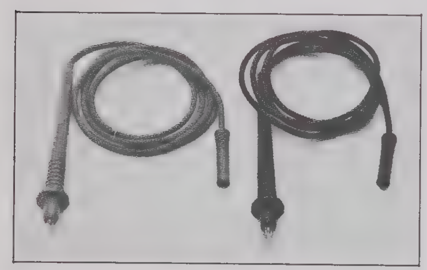
Model 1686 Vinyl Carrying Case: A soft, light weight carrying case for Models 169, 179A, 175, 177, 179A, 197, 480, 485, 580. An external pocket provides space for test leads.
Dimensions: 368mm high × 241mm wide × 76mm thick (14½ in. × 9½ in. × 3 in.)



Model 1691 General Purpose Test Lead Set: Two 0.9m (36 in.) test leads with probe tips. Banana connection to DMM.

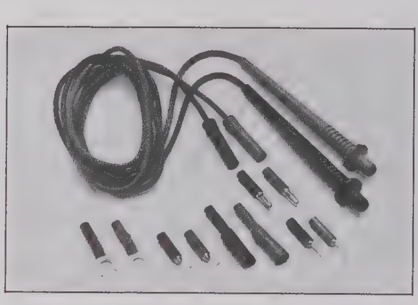


Model 1699: Contains spare parts for Model 169.

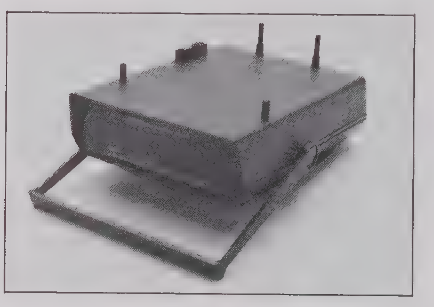


Model 1751 Safety Test Leads: 91.4cm (36 in.) test lead set supplied with each Model 175 and 197. Finger guards and shrouded banana plugs help minimize the chance of making contact with live circuitry. Also used with Model 193A.

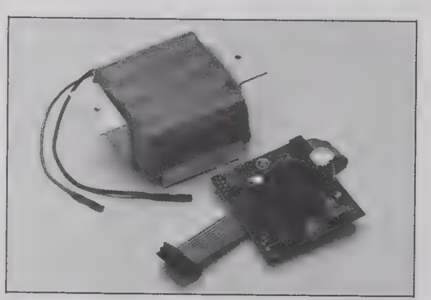
Model 1753 IEEE-488 Interface: Adds extra versatility to the Model 175 by allowing the transmission of data and commands over the IEEE-488 bus using standard IEEE-488-1978 protocol. The Model 1753 is field installable.



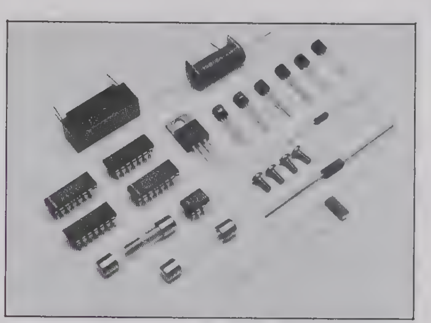
Model 1754 Universal Test Lead Kit: 10 piece test lead kit with interchangeable plug-in accessories. Kit includes: one set of test leads, 91.4cm (36 in.), 1 red, 1 black; two spade lugs, two standard banana plugs, two hooks, and two miniature alligator clips with boots. For Models 175, 193A, 196, and 197.



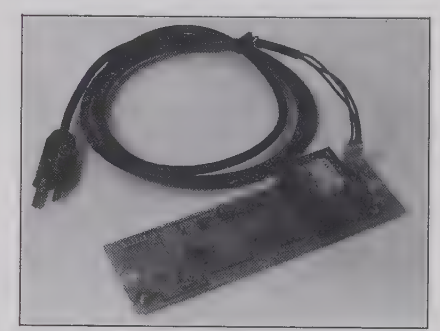
Model 1755 Calibration Interface permits automated IEEE-488 based verification and calibration of 175, 197, 485, 580 without installed interfaces. An IEEE-488 interface must be installed in the 1755 for the specific instrument under test. **Dimensions:** 89mm high × 235mm wide × 275mm deep (3½ in. × 9¼ in. × 10¾ in.)



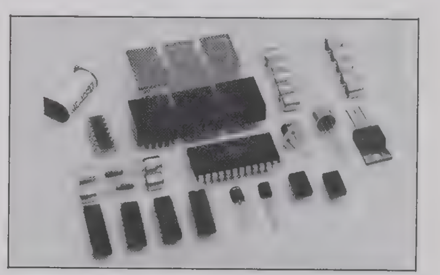
Model 1758 Rechargeable Battery Pack: For Models 175 and 485. Provides minimum six hours operation from full charge; recharges within 10 hours and is field installable.



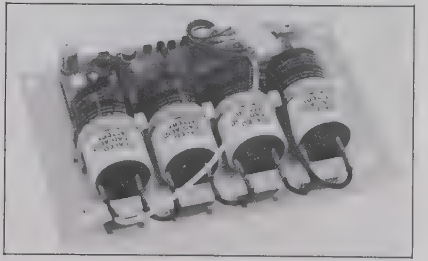
Model 1759: Contains spare parts for Model 175.



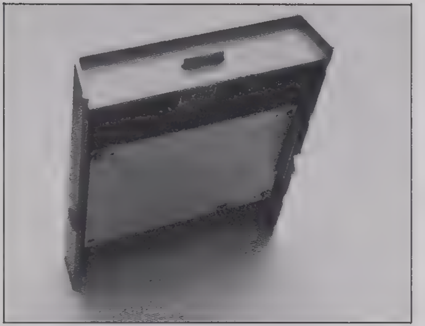
Model 1766 Battery Eliminator: Converts Model 169 to line cord operation. 105V ac to 250V ac; 10VA max; 50Hz or 60Hz; 1/32A Slo Blo fuse (250V). 0.45kg (1 lb.). Field installable.



Model 1779: Contains spare parts for Model 177.

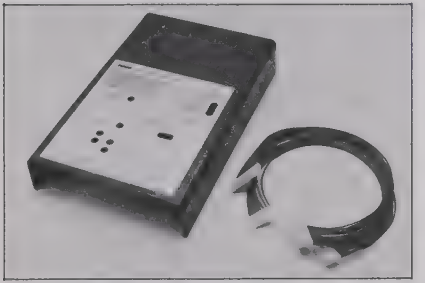


Model 1788 Rechargeable Battery Pack: 6 hours operation from full charge; 14 hour recharge; field installable. 0.9kg (2 lbs.). Use with 177, 179A, 480.

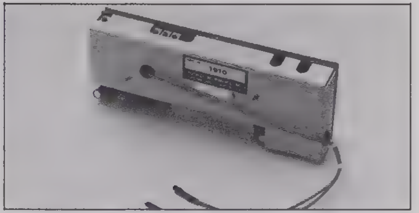


Model 1792 Isolated BCD Output: Converts reading to electrically isolated, latched, and buffered parallel BCD format. Output data include sign, overrange, busy. Use with 177, 179A, 480.

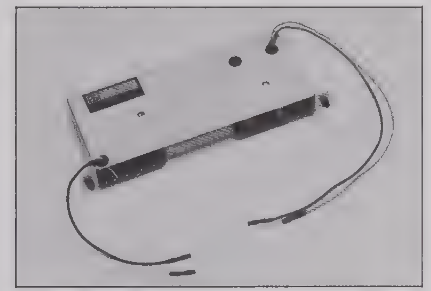
Model 1793 IEEE-488 Output: Converts readings to IEEE-488 compatible outputs for automatic data gathering. Output includes 4½-digit ASCII data, sign, and overrange. TLK ONLY or ADDRESSABLE modes. Use with 177, 179A, 480.



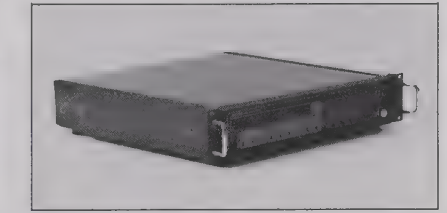
Model 1815 Maintenance Kit: Contains a calibration cover and two extender cables. The cover stabilizes internal temperature and the cables permit easy access to 181's PC boards.



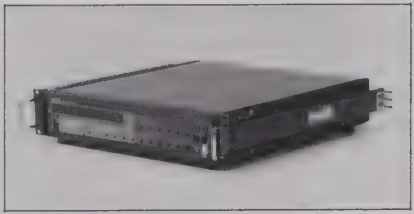
Model 1930 TRMS AC Volts Option: A True Root Mean Square (TRMS) ac plug-in option for Model 193A. The 1930 enables the Model 193A to measure the TRMS value of an ac signal. An ac+dc function is available. The Model 1930 has four ranges from 2V to 1000V.



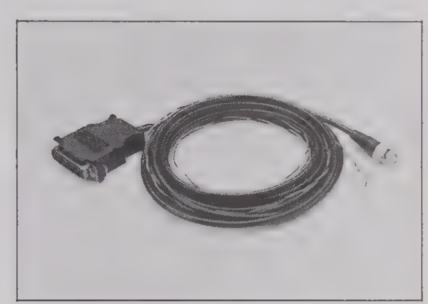
Model 1931 Current Option: The Model 1931 adds 5 ranges of current to the Model 193A with autoranging capability. The option is field installable and will measure ac currents when the Model 1930 is also installed.



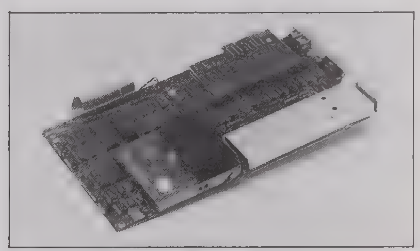
Model 1938 Fixed Rack Mount Kit consists of 2 flanged brackets and hardware for mounting the Model 193A or 194A in a standard 19 in. equipment cabinet. Can be used with Model 8000. 182mm (3½ in.) height.



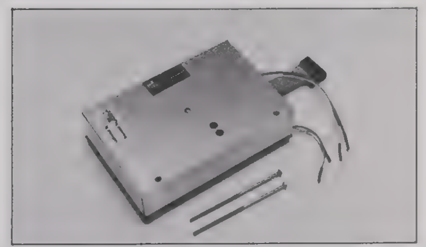
Model 1939 Slide Rack Mount Kit consists of 2 sets of flanged brackets, equipment slides, and hardware for mounting the Model 193A or 194A in a standard 19 in. equipment cabinet. Can be used with Model 8000. 182mm (3½ in.) height.



Model 1942 External Sample Trigger Cable: Enables external control of the Model 194A sample rate. DB-25P connector with 1.5m (5 ft.) of RG-58 coaxial cable terminated in a male BNC connector and 1.5m (5 ft.) of twisted pair unterminated 26 gauge wire.

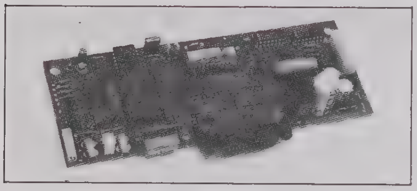


Model 1944A Channel 2 Option: Provides dual channel operation for Model 194A. Second channel is entirely independent of the first. Provides 16-bit resolution sampling up to 100kHz (8-bit up to 1MHz) with 64k byte memory.

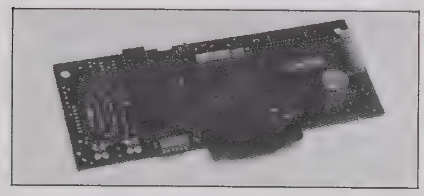


Model 1950 AC Voltage, AC and DC Current Option: Allows Model 195A to measure TRMS ac voltage from 1μV to 700V, TRMS ac current from 1nA to 2A, and dc current from 100pA to 2A. The Model 1950 plugs into the Model 195A for easy installation. Field installation requires recalibration of the 195A.

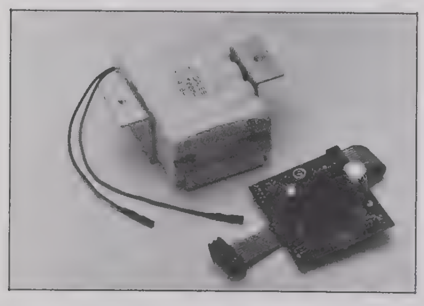
Model 1951 Input Adapter Box: Provides a means of interfacing RTD thermometer probes terminated with a 4-wire instrumentation connector to the banana jacks on the Model 195A.



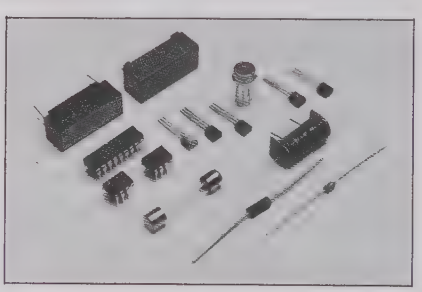
Model 1972 Analog Output/IEEE-488 Interface: Includes all the logic necessary to interface the Model 197 to the IEEE-488 bus. Contains an isolated analog output with selectable gain. The analog output can be selected to represent the value in the A/D converter or data stored in the internal memory.



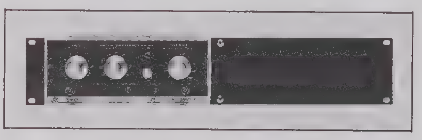
Model 1973 IEEE-488 Interface: Adds extra versatility to the Model 197 by allowing the transmission of data and commands over the IEEE-488 bus using standard IEEE-488-1978 protocol.



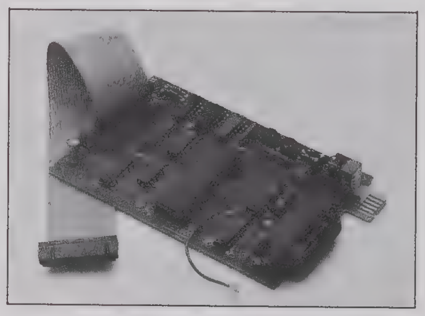
Model 1978 Rechargeable Battery Pack: Allows off-line or field operation of the Model 197 or 580. 5 hours of operation (typical) from full charge. Contains its own charging circuit and can be recharged within 10 hours. Field installable.



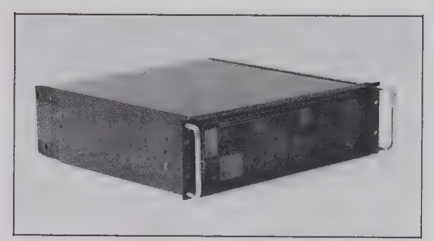
Model 1979: Contains spare parts for Model 197.



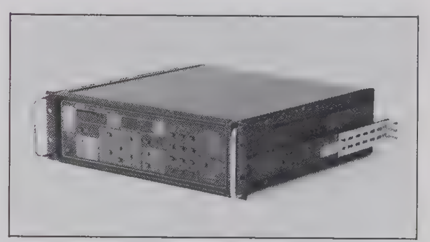
Model 2000 enables single rack mounting for Models 427 and 642. Includes a cover plate for the open area. **Dimensions (incl. instrument):** 89mm high × 483mm wide × 400mm deep (3½ × 19 × 15¾ in.).



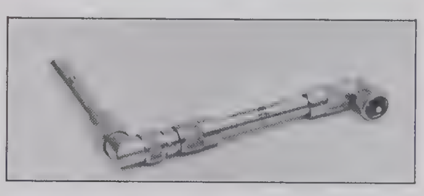
Model 2243 IEEE-488 Interface: Adds extra versatility to the Model 224 by allowing the transmission of data and commands over the IEEE-488 bus. The 2243 incorporates a separate digital I/O port that may be used to monitor and control external logic.



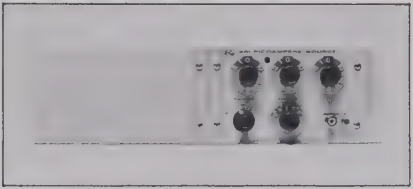
Model 2288 Fixed Rack Mount Kit: Consists of 2 flanged brackets and hardware for mounting the Model 228 in a standard 19 in. equipment cabinet. Can be used with Model 8000. 132mm (5¼ in.) height.



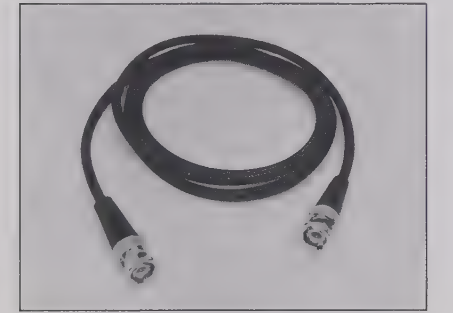
Model 2289A Slide Rack Mount Kit: Consists of 2 sets of flanged brackets, equipment slides, and hardware for mounting the Model 228 in a standard 19 in. equipment cabinet. Can be used with Model 8000. 132mm (5¼ in.) height.



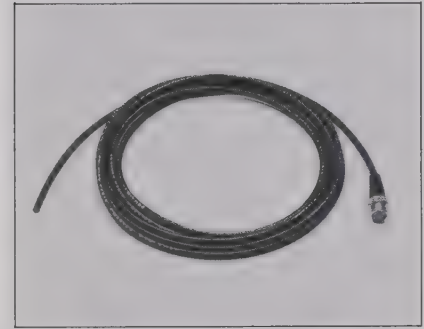
Model 2503 Static Detector Probe: Designed to detect voltage due to charge on relatively small surface areas. Solid coaxial 13mm (½ in.) diameter tube with 89mm (3½ in.) head, 89mm (3½ in.) coupler, 25mm (1 in.) adapter, and two 90° angle adapters which may be placed at various junctions along the tube. It gives a 10,000:1 ±10% division ratio when used with Model 610C and held 6mm (¼ in.) away from a charged plane of at least 13mm (½ in.) diameter. Output is a UHF male plug. (Use only with Model 610C.)



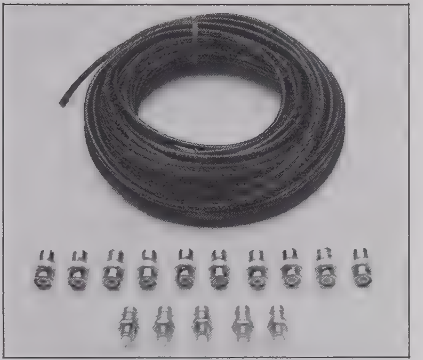
Model 4003A is a single side-mounted kit used to mount one Model 225, 261, or 26000 series.
Dimensions (including mounted instruments): 133mm high × 483mm wide × 311mm deep (5¼ × 19 × 12¾ in.).



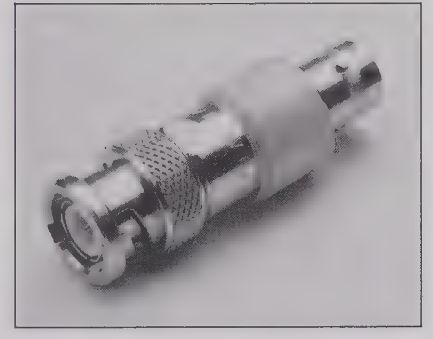
Model 4801 Input Cable: Low noise coaxial cable, 1.2m (48 in.) in length, with male BNC to male BNC connectors. For use with Models 480 and 485.



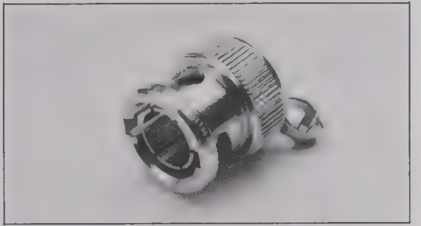
Model 4802-10: 3m (10 ft.) of low noise coaxial cable with male BNC connector at one end and unterminated at the other.



Model 4803 Low Noise Cable Kit: Includes 50 ft. of low noise coaxial cable, 10 male BNC connectors, and 5 female BNC chassis-mount connectors.

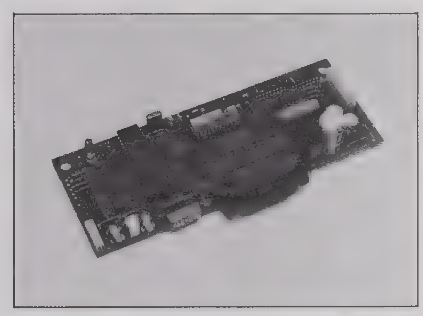


Model 4804: 2-slot male BNC to 2-lug female triaxial adapter. Used to adapt triaxial cables to 2-lug BNC input connectors.

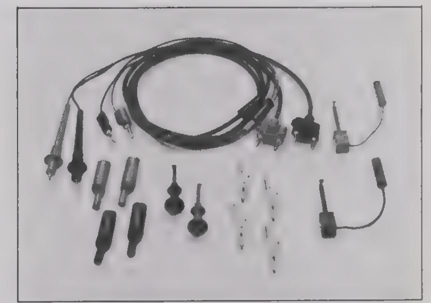


Model 4851: BNC shorting plug.

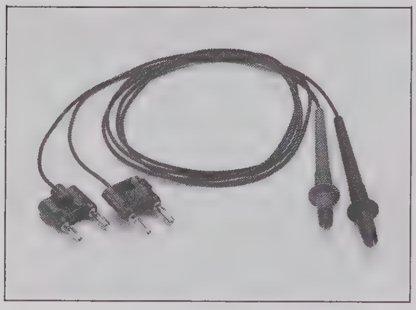
Model 5801: Test lead pouch for Models 5804, 5805, and 5806 test leads used with Model 580.



Model 5802: Isolated analog output/IEEE-488 interface for Model 580.

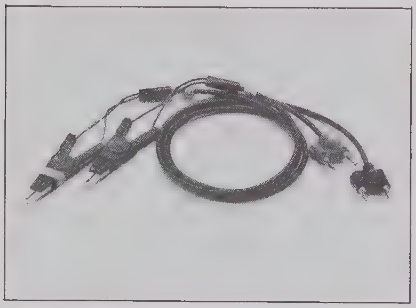


Model 5804 Test Lead Set: Designed to be used with Keithley instruments that measure 4-terminal resistance. **Contains:** 2 test leads, 0.9m (36 in.), red & black; 2 test clips, red & black; 2 plunger clip adapters, red & black; 2 alligator clips with boots (accept standard test probe tip); 2 alligator clips with boots (barrels accept standard banana plugs).

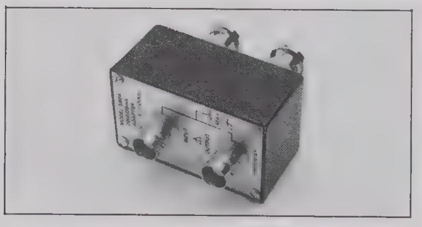


Model 5805 Kelvin Probes: 2 spring-loaded test probes, red & black, 0.9m (36 in.) with banana plug termination. Designed to be used with Keithley instruments that measure 4-terminal resistance. A package of 8 replacement contacts (P/N CS-551) is available.

Model 5805-12: Similar to 5805 but 3.6m (12 ft.) in length.



Model 5806 Kelvin Clip Lead Set: 2 clip test leads, red & black, 0.9m (36 in.) with banana plug termination. Designed to be used with Keithley instruments that measure 4-terminal resistance. A package of 8 replacement rubber bands (P/N GA-22) is available.



Model 5904: 20nF/20mS adapter. Extends range of Model 590/100k.

Model 5905: Calibration sources for Model 590/1M. Includes 18pF, 180pF, 1.8nF, 4.7pF, 47pF, 470pF capacitance sources and 180μS, 1.8mS, 18mS conductance sources. Also includes CS-566 right angle male-to-female BNC connector, CS-567 female BNC shorting cap, and 5900-313 storage case.

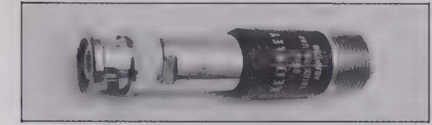
Model 5906: Calibration sources for Models 590/1M, 590/100k, 590/100k/1M, and 5904. Includes 1.5pF, 18pF, 180pF, 1.8nF, 18nF, 0.5pF, 4.7pF, 47pF, 470pF, 4.7nF capacitance sources and 1.8μS, 18μS, 180μS, 1.8mS, 18mS conductance sources. Includes two storage cases.

Model 5907: Calibration sources to calibrate cable and matrix. Includes 1.8nF and 470pF capacitance sources, 2 BNC female-to-female barrels (CS-565), and 5900-312 storage case.

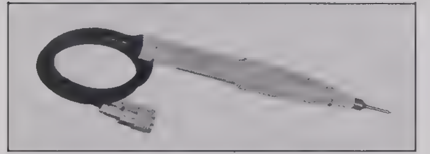
Model 5955: Calibration sources for Model 595. Includes 18nF, 1.8nF, 180pF capacitance sources and storage case.

Model 6011: 3 feet of triaxial cable (SC-22) terminated with a triaxial plug on one end and 3 alligator clips on the other. For use with Models 220, 224, 602, 614, 617, and 619.

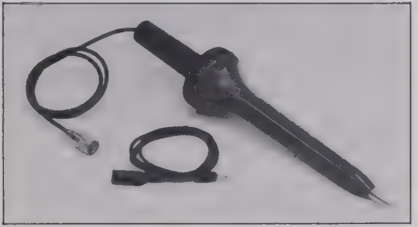
Model 6011-10: 10 feet of triaxial cable (SC-22) terminated with a triaxial plug on one end and 3 alligator clips on the other. For use with Models 220, 224, 602, 614, 617, and 619.



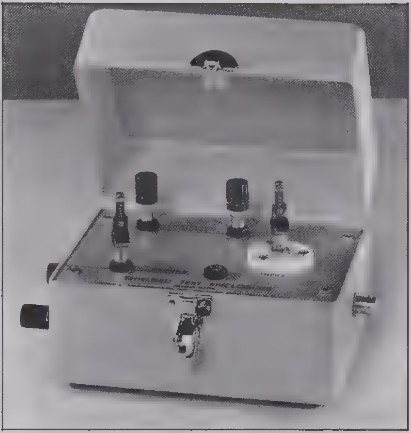
Model 6012 Triax to UHF Adapter: Permits using Models 220, 224, 602, 614, 617, and 619 with all Keithley electrometer accessories having UHF type connectors.



Model 6101A Shielded Test Lead: Straight-through probe and shielded lead with 0.8m (30 in.) of shielded low noise cable terminated by Teflon-insulated UHF connector. Use with 6012 adapter for Models 602, 614, 617, and 619.



Model 6103C Voltage Divider Probe: Permits voltage measurement to 30kV and has a 1000:1 division ratio. Accuracy is ±5% of reading. Its $3.8 \times 10^{11}\Omega$ input resistance permits use with Keithley electrometers and other high impedance multimeters. Connector is a UHF male plug. Requires the 6012 Coaxial to Triaxial Adapter when used with Models 602, 614, 617, and 619. Lead length is 0.8m (30 in.).



Model 6104 Test Shield: Facilitates resistance, current, or voltage measurements up to 1200V with 2- or 3-terminal guarded connections. Excellent electrostatic shielding, high isolation resistance, easy connection to most Keithley electrometers and power supplies. Clips plug into banana jacks, allowing modified connections. BNC connector on one side, binding posts on the other.

Model 6105 Resistivity Chamber: Guarded test fixture for measuring volume and surface resistivities. Assures good electrostatic shielding, high insulation resistance. Use with Keithley picoammeters and voltage supplies, such as Model 247. System permits direct measurement of volume resistivity up to $10^{19}\Omega$-cm (on samples 0.1cm thick) and surface resistivity up to $10^{18}\Omega$ in accordance with ASTM procedures. Accommodates sheet samples 64 to 102mm (2¼ in. to 4 in.) in diameter and up to 6.4mm (¼ in.) thick. Use excitation voltages up to 1000V. Maintains good sample contact with uniform 1 pound pressure on smooth parallel-surfaced samples. An interlock switch automatically disconnects the excitation voltage upon opening the lid.

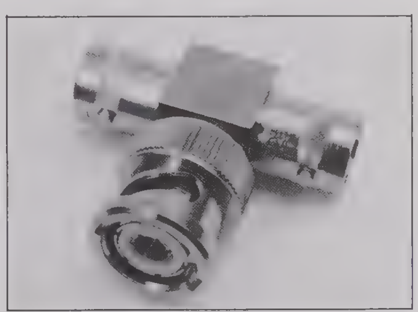
Supplied Accessories:

1 Model 32418 UHF to MHV cable (to Model 247)

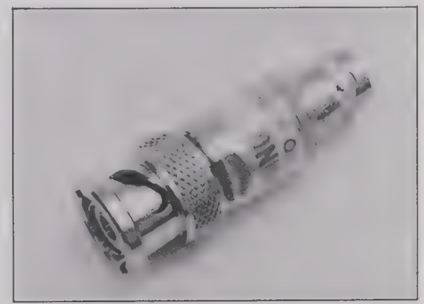
1 Model 4801 BNC to BNC cable (to Model 485)

1 Model 6147 BNC to triax adapter to allow use of Model 602, 614, or 617 in place of 485.

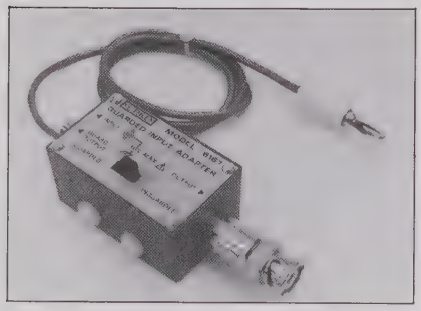
1 CS-115 UHF to BNC adapter to allow use of Model 610C in place of 485.



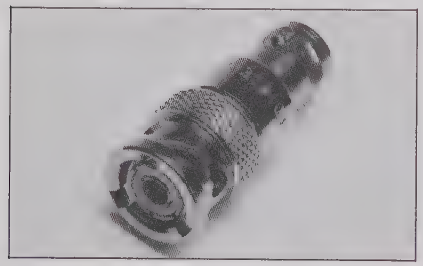
Model 6146 Triax Tee Adapter: To connect multiple inputs to Models 602, 614, 617, and 619; allows easy connection of external feedback elements.



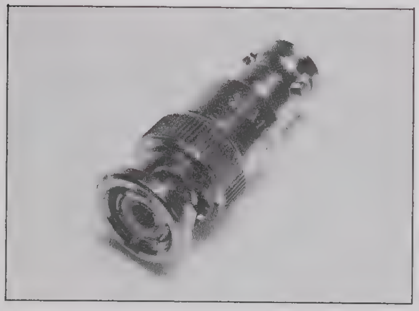
Model 6147 Triax to BNC Adapter: Permits using Models 220, 224, 602, 614, 617, and 619 with accessories having BNC connectors.



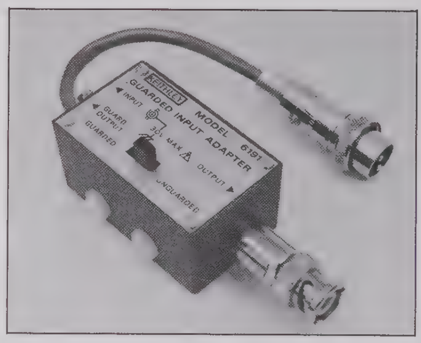
Model 6167 Guarded Input Adapter: Reduces effective cable capacity by driving the inner shield of the triaxial cable at Guard potential. For use with Models 220, 224, and 614. Triax female to triax male.



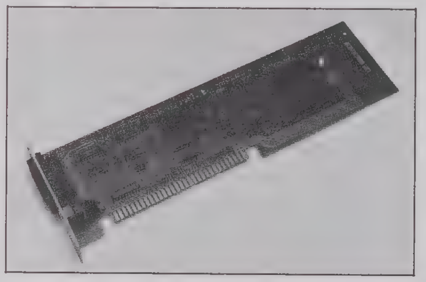
Model 6171: 3-slot male to 2-lug female triaxial adapter. For use in adapting 7024 and 6011 cables to 3-lug triaxial input connectors.



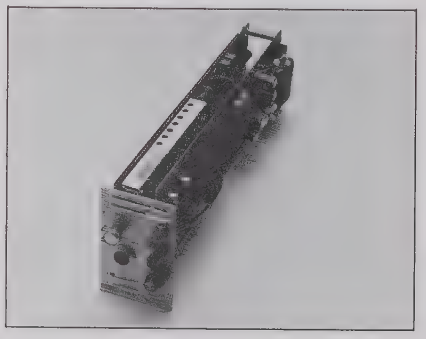
Model 6172: 2-slot male to 3-lug female triaxial adapter. For use in adapting Models 220, 224, 602, 614, 617, and 619 inputs to 3-lug triaxial cables.



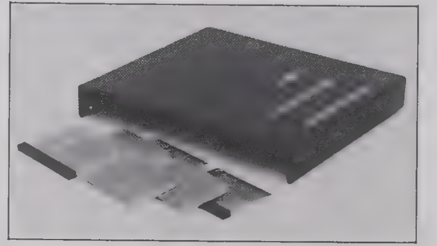
Model 6191 Guarded Input Adapter: Similar to Model 6167 except for use with a Model 619 electrometer module. Triax female to triax male.



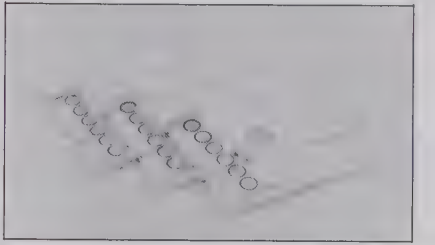
Model 6193: IEEE-488 interface for Model 619.



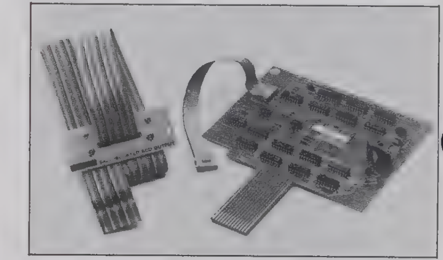
Model 6194: Second electrometer module for channel B of Model 619.



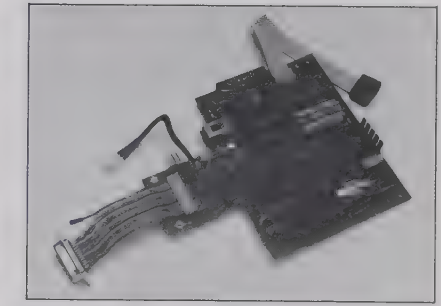
Model 6195 Maintenance Kit: For Model 619 Electrometer/Multimeter; includes calibration cover and three extender boards. Calibration cover allows the 619 to reach normal operating temperatures, and has adjustment openings marked to facilitate calibration adjustments. Three extender cards allow easy access to internal boards for troubleshooting.



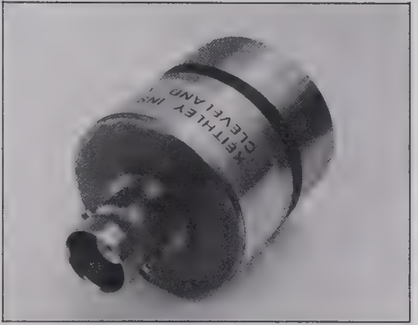
Model 6421: Refill desiccant paper pack for Model 642. One piece at a time may be installed in the remote head as needed. Each of the three pieces is individually packaged in its own moisture resistant bag.



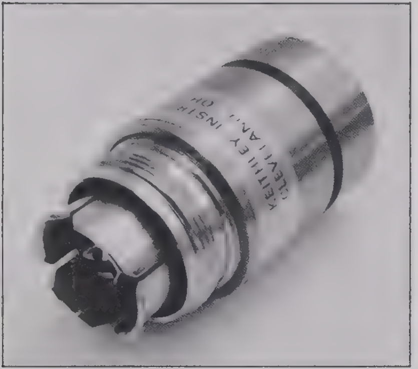
Model 6422 Isolated BCD Output: Converts the displayed reading on Model 642 to an electrically isolated, latched, and buffered parallel BCD format. Additional data lines include sign, overrange, and busy.



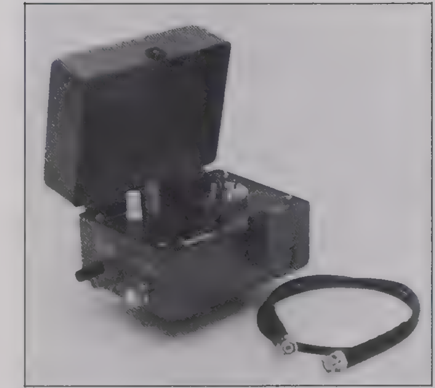
Model 6423 Isolated IEEE-488 Output: Provides the logic and control functions necessary to interface Model 642 to an IEEE-488 bus.



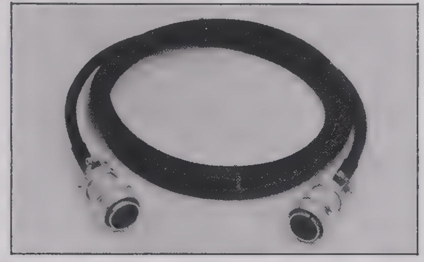
Model 6424: BNC adapter for use with Model 642. It is the most convenient connection method, limited by currents generated in the flexible cabling.



Model 6425: Converts the input of Model 642 to a GR874® rigid air line connection, permitting decades of improvement in current resolution over Model 6424.

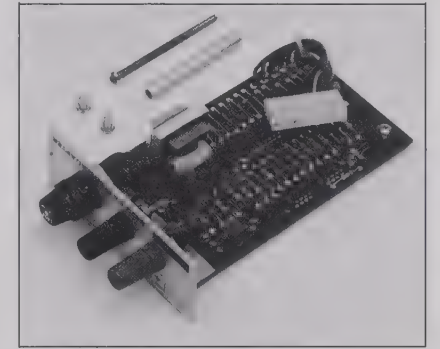


Model 6426 Sapphire-Insulated Test Box: Extends the integrity of the sapphire insulation into a test box which mounts on the remote head, when used with Model 642. Useful for testing semiconductor leakage or high resistance measurements on small geometry parts. Custom input fittings may be made to the dimensions indicated in the 642 Instruction Manual.

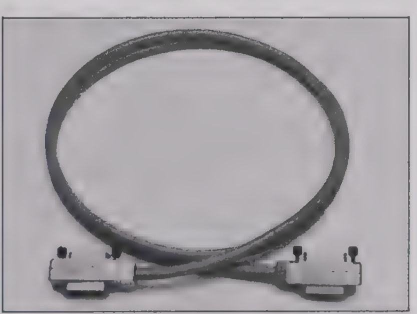


Model 6427-20: 20 ft. remote head to mainframe interconnect cable for Model 642.

Model 6427-50: Similar to 6427-20 but 50 ft. with remote power supply.

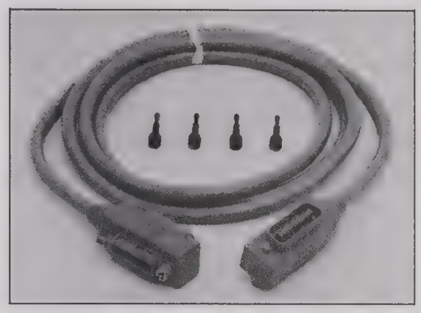


Model 6428 Battery Adapter: For operating 642 from external 12V battery; field installable.



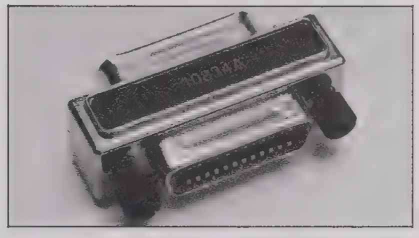
Model 7007-1: 1m (3.3 ft.) shielded IEEE-488 interface cable with shielded connector on each end (metric).

Model 7007-2: Similar to 7007-1 but 2m (6.6 ft.).

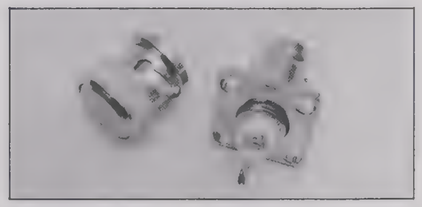


Model 7008-3: 0.9m (3 ft.) IEEE-488 digital cable terminated with a standard IEEE-488 connector on each end, with metric mating screws.

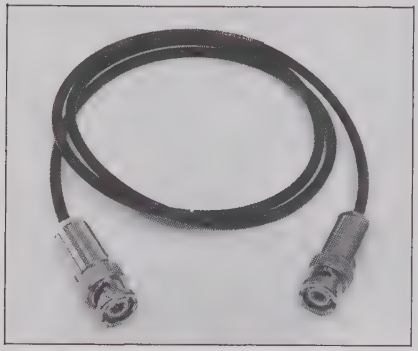
Model 7008-6: Similar to 7008-3 but 1.8m (6 ft.).



Model 7010 Shielded IEEE to IEEE Adapter: Provides additional clearance between IEEE-488 cable and rear panel, allowing easier access to switches, cables, and other connectors.

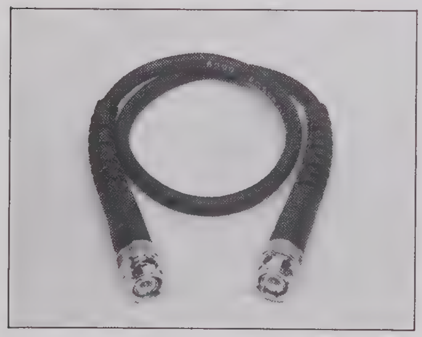


Model 7023 Female Triaxial Connector: Chassis mount connector mates with Keithley accessory cables 6011 and 7024 series.



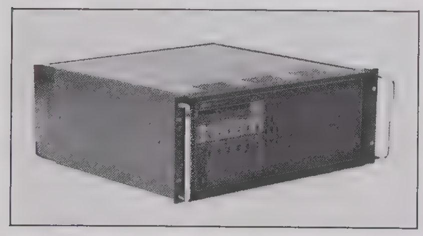
Model 7024-3: 0.9m (3 ft.) triaxial cable (SC-22) with two lug male triax connectors on each end.

Model 7024-10: Similar to 7024-3 but 3.0m (10 ft.)

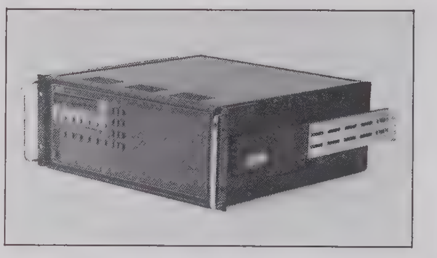


Model 7051-2: 0.6m (2 ft.) BNC to BNC cable (RG-58C).

Model 7051-5: Similar to 7051-2 but 1.5m (5 ft.).

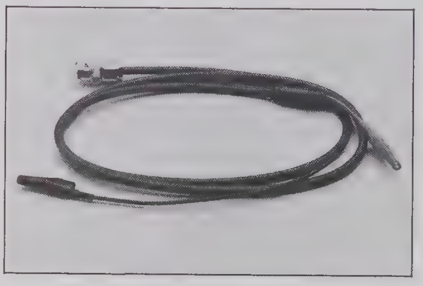


Model 7068 Fixed Rack Mount Kit: Two 7 in. flanged brackets and hardware for mounting Model 706 in a standard 19 in. equipment cabinet. Can be used with Model 8000.

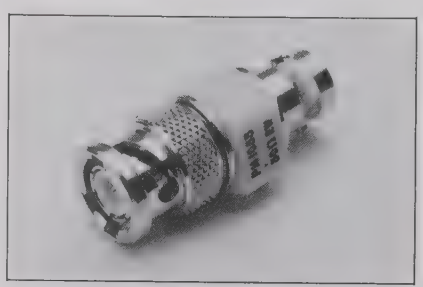


Model 7069 Slide Rack Mount Kit: Two sets of flanged brackets, slides, and hardware for mounting Model 706 in standard 19 in. equipment cabinet. Can be used with Model 8000.

Model 7401: Type K thermocouple wire kit includes 30.5m (100 ft.) of type K (chromel-alumel) thermocouple wire.



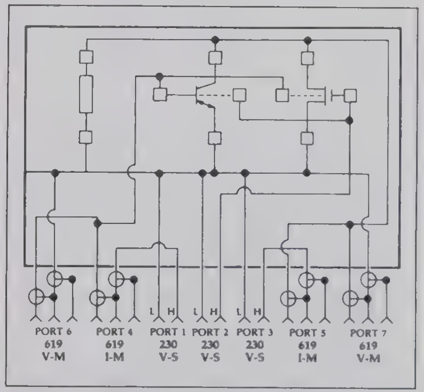
Model 7754-3 BNC to Alligator Cable: 0.9m (3 ft.) terminated on one end with a BNC plug and on the other with two alligator clips.



Model 7755 50Ω Feed-Through Terminator: BNC-to-BNC adapter for terminating RG 58 cable in its characteristic impedance. VSWR <1.1, dc-250MHz.

Model 8000 is a 28 in. high equipment cabinet that is open on both ends. It will accept all Keithley rack mounting kits as well as most rack kits provided with other instrumentation. The dark brown 8000 comes fully assembled, with handles permanently installed on each side. 100 chrome Phillips head screws with mylar washers and clip nuts are provided for instrument mounting. Rack mounting kits are available separately. See Selector Guide on page 85.

Dimensions: 711mm high × 484mm wide × 533mm deep (28 in. × 19 in. × 21 in.).

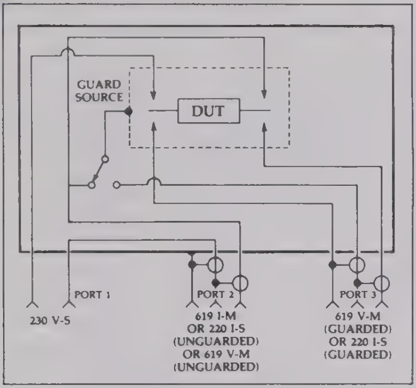


Model 8001 Semiconductor Test Fixture: Allows convenient semiconductor characterizations with Keithley measurement equipment. Sockets are provided for a bipolar transistor, a MOSFET, and a diode.

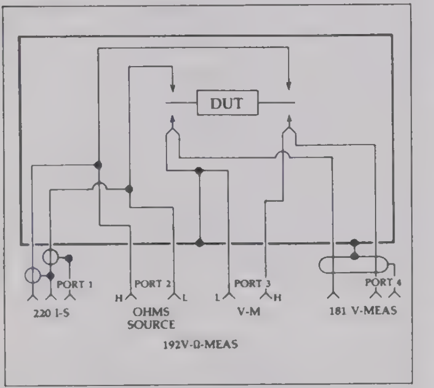
Inputs: 3 pairs of 5-way binding posts.

Outputs: 4 triaxial connectors.

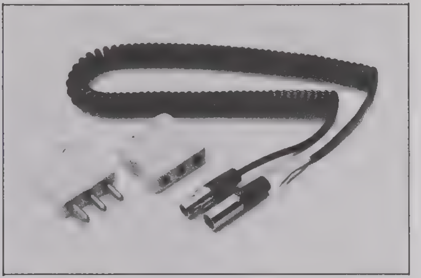
Supplied Cables: 3 Model CA-18-1 dual banana cables; 4 Model 7024-5 triaxial cables.



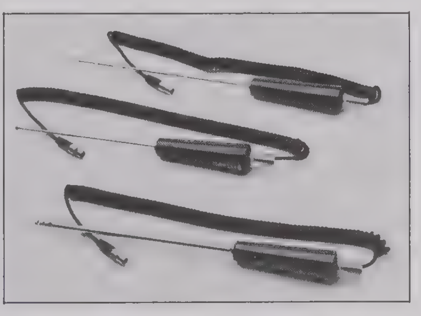
Model 8002 High Resistance Test Fixture: Enables high resistance measurements up to 100TΩ. The 8002 is designed to minimize leakage currents which could become a significant portion of the measurement if not controlled.
Inputs: 1 pair of 5-way binding posts.
Outputs: 2 triaxial connectors.
Supplied Cables: 1 Model CA-18-1 dual banana cable; 2 Model 7024-5 triaxial cables.



Model 8003 Low Resistance Test Fixture: Four-terminal device which eliminates the effects of test lead resistance by providing separate current source and voltage sensing terminals.
Input: 1 triaxial connector.
Outputs: 2 pairs of 5-way binding posts, 1 special low-thermal connector for nanovoltmeter.
Supplied Cables: 1 Model 7024-5 triaxial cable; 1 Model 262-315 low thermal cable; 2 Model CA-18-1 dual banana cables.



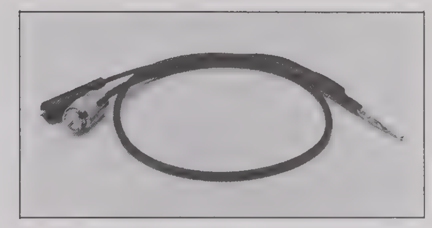
Model 8691 RTD Connector Kit: Contains one male 4-wire connector, one female 4-wire connector with attached coiled cable (mates with connector on 1951), and male and female 3-wire adapters. Extended cable length: 1.5m (5 ft.).



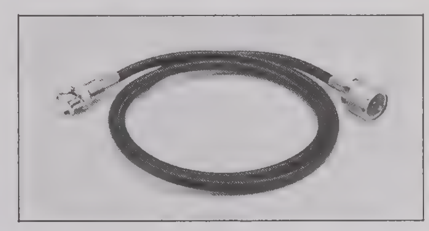
Model 8693 General Purpose/Immersion Probe: Platinum RTD sensor. Designed for immersion in liquids as well as other general purpose applications. Measures from −220°C to +630°C; the probe has a basic tolerance of ±0.3°C at 0°C.
Probe Length: 20cm (8 in.).
Extended Cable Length: 1.5m (5 ft.).

Model 8695 Surface Probe: Platinum RTD sensor. Designed to measure the flat surfaces of solids from −50°C to +260°C; the probe has a basic tolerance of ±0.3°C at 0°C.
Probe Length: 15cm (6 in.).
Extended Cable Length: 1.5m (5 ft.).

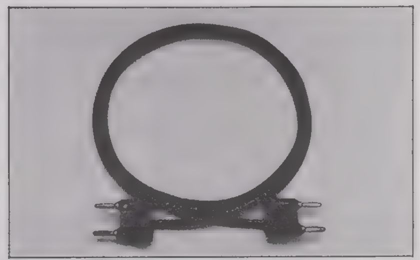
Model 8696 Air/Gas Probe: Platinum RTD sensor. Has an exposed junction within a protective shroud. Measures from −50°C to +260°C; the probe has a basic tolerance of ±0.3°C at 0°C.
Probe Length: 20cm (8 in.)
Extended Cable Length: 1.5m (5 ft.)



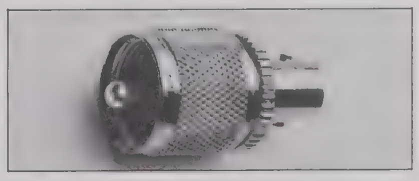
19072 Input Cable: 0.9m (3 ft.) of coaxial cable (SC-9) with UHF connector on one end and alligator clips on the other. For use with Model 610C.



32418: UHF-MHV cable supplied with Model 6105 for connection to Model 247. Cable length 0.9m (3 ft.).



CA-18-1: 1.2m (4 ft.) shielded cable terminated with a dual banana plug on each end. For use with binding post inputs.



CS-115 UHF-BNC Adapter: Permits using Model 610C with accessories having BNC connectors.

CS-141: Male triaxial cable mount connector for use with SC-22 cable. Mates to Models 220, 224, 602, 614, 617, and 619.

SC-9: Low noise coaxial cable without connectors (sold by the foot).

SC-22: Low noise triaxial cable without connectors (sold by the foot).

This Technical Digest is designed to serve three functions: first, to help you decide if you need a data acquisition and control system; second, to discuss the variables that deserve consideration in selecting a system; and third, to deliver specifications and descriptions of Keithley's products.

Do you need a workstation for laboratory data acquisition and control?

Workstation? These systems are used with personal computers. The computer provides intelligence to run the system, analyze the data, and provide control. PCs are inexpensive and easy to use, but you should feel comfortable using a PC if you are considering this type of system.

Laboratory or OEM? Most of these systems are used for research, in particular for applications in chemistry, life sciences, and mechanical testing. The reason for the concentration in research is that both the hardware and software in these products allow for a great deal of variety in the types of experiments or procedures that are run. This does not restrict the systems to use in research; a recent survey shows that about 20% are used in OEM applications. The issue is whether you need a very versatile system, or if a single-use or turnkey system would be more appropriate.

FIGURE 1: Laboratory Automation

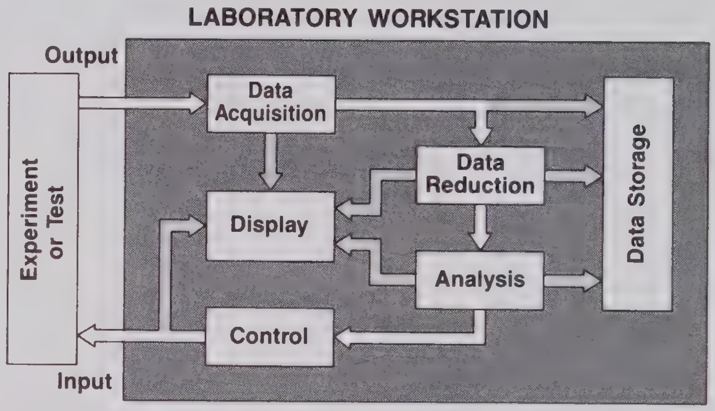
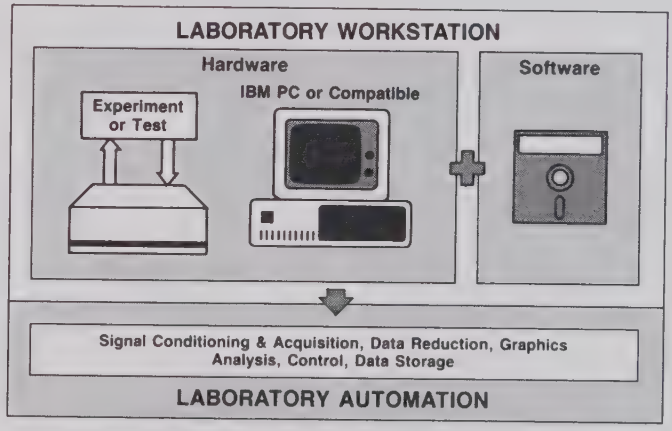


FIGURE 2: Laboratory Workstation



Data Acquisition? There are many types of data acquisition; here we are discussing measurements of multiple inputs and outputs, typically 16 analog inputs, 2 analog outputs, 16 digital inputs, and 16 digital outputs, but these systems can usually handle many more. The frequency of the input signals is usually low (under 100Hz), but most systems offer single-channel sampling rates of at least 20kHz. Finally, the phenomena being observed should be of sufficient duration that the data must be stored for analysis.

Prior to the advent of data acquisition and control systems, this type of measurement was made with a recorder, with signals above a few Hz requiring an oscillographic recorder. In these applications the instrument did little more than log data. A data acquisition and control system, however, opens the way to inexpensive but complete laboratory automation. This includes data acquisition, data reduction, analysis, storage, and control.

Control? This is perhaps the most significant aspect of these systems. They allow you to close the loop and dynamically change an experiment based on measured results. If you are heading towards laboratory automation you need control, and you need a data acquisition and control workstation (**Figure 1**).

Considerations in Selecting a Data Acquisition & Control System

A data acquisition system consists of the hardware and software that make up a laboratory workstation. Most data acquisition hardware is supported with at least one software package, usually supplied by the hardware manufacturer. In addition, some data acquisition products are supported by third-party software packages. This is important, since software is the tool that will increase your productivity and get your workstation up and running. Hardware, however, defines the system's basic performance, and is the first thing to consider in selecting a system (**Figure 2**).

Architectures. There are three major architectures in PC-based systems. A "board-level" product is a single printed circuit board that fits into one of the slots of the personal computer. The board provides a rear connector for attaching input and output signals. These boards, available from a number of manufacturers contain all the necessary circuitry to perform limited data acquisition tasks. The board-level product is traditionally the lowest cost ($400 - $1500) and simplest of the three architectures (**Figure 3**).

Expansion chassis architecture is more complex and more expensive than board-level products, but yields greater performance in most cases. A cable connects the PC to a separate "box" which holds all of the data acquisition modules that perform the actual I/O (input and output). Within this type of architecture there are two categories: boxes fully controlled by the PC ($2000 - $5000), and intelligent boxes containing internal microprocessors (typically greater than $5000). An example of a box fully controlled by the PC is the Keithley Series 500 Scientific Workstation (**Figure 4**).

Recently, a new architecture was introduced that combines the low-cost advantage of board-level products with the performance advantages of an expansion chassis architecture. This type of architecture is being introduced in the Keithley System 570 Data Acquisition Workstation. All of the digital logic, including counters for precise timing, dc-dc converter supplying the necessary power for the analog circuitry, and two digital-to-analog converters, reside on a single board that plugs directly into the PC. Attached to the PC plug-in card through a 15-foot cable is an external box. All of the electrically-sensitive functions are performed in the external box, including signal connection, signal conditioning, and analog-to-digital conversion (**Figure 5**).

FIGURE 3: Board Level Configuration

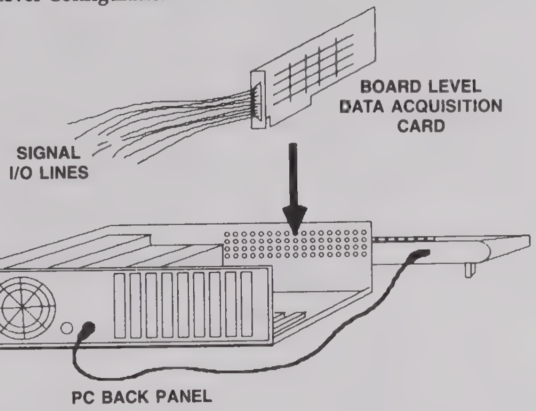
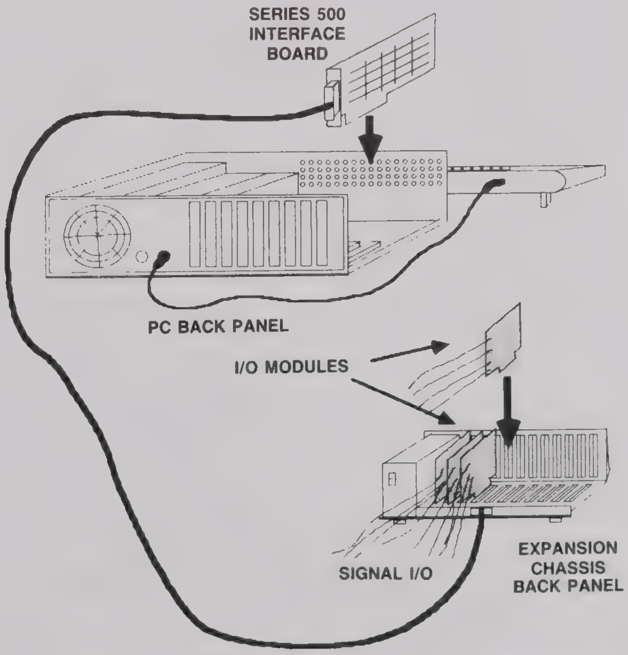


FIGURE 4: Typical Expansion Chassis Configuration



Inputs and Outputs. All of the previously mentioned architectures contain the basic analog and digital I/O functions. But the channel capacity in board-level products is considerably less than in expansion chassis products. This reduced capacity is due primarily to the PC's limited rear panel space, where the I/O connector is attached. If you need more I/O channels or a different I/O function, you must insert yet another board-level product into your PC. After you fill up the slots in your PC with necessary options like an RS-232 card for your printer, a RAM expansion board, a disk drive controller board, and your graphics card, there are not many available slots for a group of data acquisition boards. An example of the channel capacity for board-level products is eight differential analog inputs (which can be configured into 16 single-ended analog inputs), two analog outputs, and two eight-bit digital I/O ports.

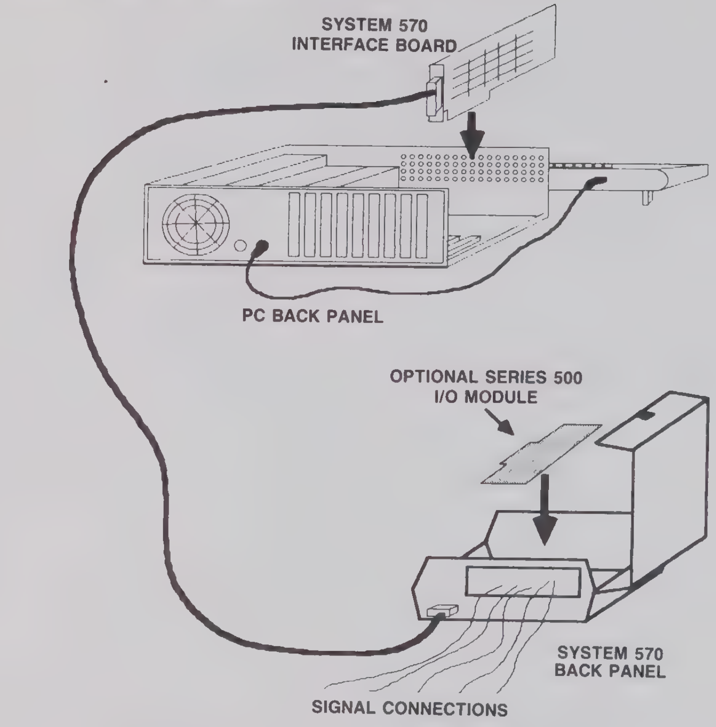
If your task is small, well-defined, and static, a board-level product may be the answer. But if your task doesn't fit these guidelines, the expansion chassis architecture should be considered. The expansion chassis houses data acquisition

I/O modules which cover all of the general purpose I/O functions in board-level products, and also allows the user to custom configure his data acquisition system for a specific test. Keithley has more than 20 modules for its Series 500 Data Acquisition System.

A modular architecture allows the manufacturer to offer improved I/O modules as technology permits and to supply special function modules as they are needed. Special functions are usually a sub-classification of standard I/O types, and could include such functions as signal conditioning for transducers (e.g. strain gages and thermocouples), transducer excitation (e.g. RVDT/LVDT), and stepper motor control (**Figure 6**).

Like board-level products, the Keithley System 570 has all of the common data acquisition I/O elements built-in. These elements include 32 single-ended or 16 differential analog input channels with software-programmable gains, 12-bit 31kHz analog-to-digital conversion, 16 channels of digital input, 16 channels of digital output, and 16 channels of solid-state relay control. Beyond the built-in functions, one expansion slot is included in the external box to allow the user to add almost any additional functional module from the Series 500 I/O module library. This additional feature, not found in the traditional board-level products, adds a dimension of flexibility previously reserved for expansion chassis products.

FIGURE 5: System 570 Configuration



Signal Integrity. The location of the analog circuitry in a data acquisition system is very important, since signal conditioning amplifiers and the analog-to-digital signal processing circuitry are very sensitive to electrical noise. The integrity of the signal being measured is dependent on a low-noise environment for the analog circuitry.

In the expansion chassis architecture, the sensitive analog circuitry resides in the external box. This places the circuitry far from the electrically noisy PC environment of high speed digital circuitry, crystal oscillators, microprocessors, and coprocessors. In contrast, the board level products house all of the analog circuitry inside the PC, which could potentially lead to poor analog signal integrity if not completely shielded. For example, if the three least significant bits of your 16-bit A/D (analog-to-digital) converter have been corrupted by noise, then the A/D converter becomes effectively a 13-bit A/D. The reduction in analog signal resolution can be substantial, a critical point when measuring low-level signals that may not be of much greater magnitude than the noise level. (For example, the output of a K-type thermocouple is less than a millivolt at room temperature.)

Signal Connections. Board-level products connect all of their signal I/O through a connector on the rear panel of the PC. To reduce the difficulty in configuring a mating connector with all of the necessary signals, most board-level manufacturers offer a screw terminal board as an option at an extra cost of approximately $130. The terminal board is an extension of the signal bus and resides outside the PC. Expansion chassis products typically connect all of the signal lines directly to the appropriate I/O module in the box. Like expansion chassis products, the System 570 has all of its signal connections external to the PC, allowing signal connections to be made quickly and easily.

Signal Isolation. Most data acquisition system manufacturers offer differential analog input capabilities, but not all offer signal isolation. Signal isolation is an important consideration when measuring a differential signal that has a high common-mode voltage. For example, if you are measuring a differential voltage that is between +10 volts and −10 volts, and the signal lines are both floating at 40 volts above ground, isolation is necessary. Due to added expense and limited board area, board-level products typically do not contain isolation circuitry.

Expansion chassis products offer I/O modules with a choice of isolated or non-isolated inputs and outputs.

Hardware Operation. Board-level products are memory mapped systems; the hardware on the board is accessed by the PC in the same manner as it accesses its own memory. Apart from the memory mapped products are the "intelligent" systems. Usually a manufacturer will categorize a product as "intelligent" if it includes a microprocessor (**Figure 7**).

In addition to a microprocessor and internal memory for processor use and I/O buffer space, there is an internally resident real-time operating system. Communication is through either an RS-232 port or an IEEE-488 port. The internal memory is capable of storing acquired data as well as doing some signal processing. The Series 500, in comparison, does not contain a microprocessor and relies on the PC for processing power and memory.

In intelligent systems, there is duplication of functions between the PC and the data acquisition system: both include a microprocessor, memory, and communication I/O. Functional redundancy enables the intelligent system to outperform the memory-mapped system in certain applications such as remote and stand-alone monitoring. In many laboratory workstation environments, however, the intelligent system can be an expensive "overkill".

When using a PC with an intelligent data acquisition system, one must adhere strictly to a certain amount of command and data protocol. For users who intend to write their own PC software in the language of their choice, an intelligent system running its own language may introduce a considerable amount of communication protocol burden to the programming task. For example, an intelligent system buffers all of the acquired signals in its own memory, and the PC must request the data. Transmitting large amounts of data over a standard bus like the RS-232 may take an unacceptable amount of time.

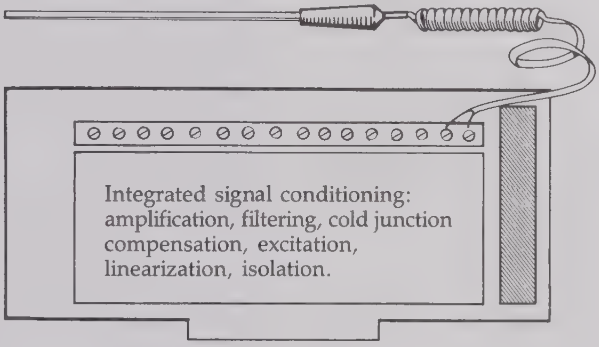
Choosing a PC-based data acquisition system should start with an evaluation of hardware, since hardware defines the basic capabilities of the system. The hardware issues are I/O capability, signal integrity, signal connection, and remote or stand-alone monitoring; and most of these issues are a function of the system's architecture.

FIGURE 6: Direct I/O Connection

Direct connection of transducers and I/O eliminates the need for external conditioning. Signals with different ranges and characteristics from different instruments and transducers of all types are connected to the Series 500 without the need for preamplifiers, custom networks, or jumper cables. Screw terminals supply the universal solution for interfacing I/O lines. Banks of channels from each card are detached to allow easy connection of I/O, and are simply re-plugged into the Series 500 module.

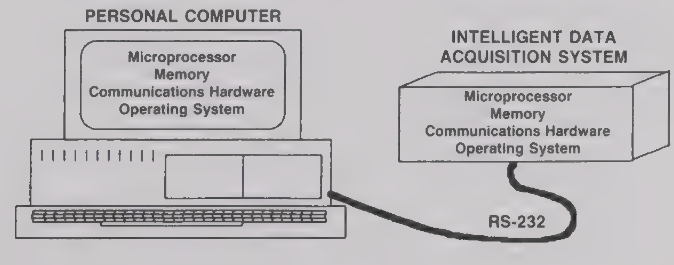
Local signal conditioning is selected by on-card DIP switches. Precision instrumentation amplifiers on many of the cards, with switch-selectable gains to ×100 volts/volt, provide true differential input for low-level signals.

Programmable signal conditioning permits an unprecedented versatility in responding to individual signal requirements. A high-speed programmable gain amplifier permits the additional amplification of individual channels to be established from the application software and updated instantly with a single parameter.

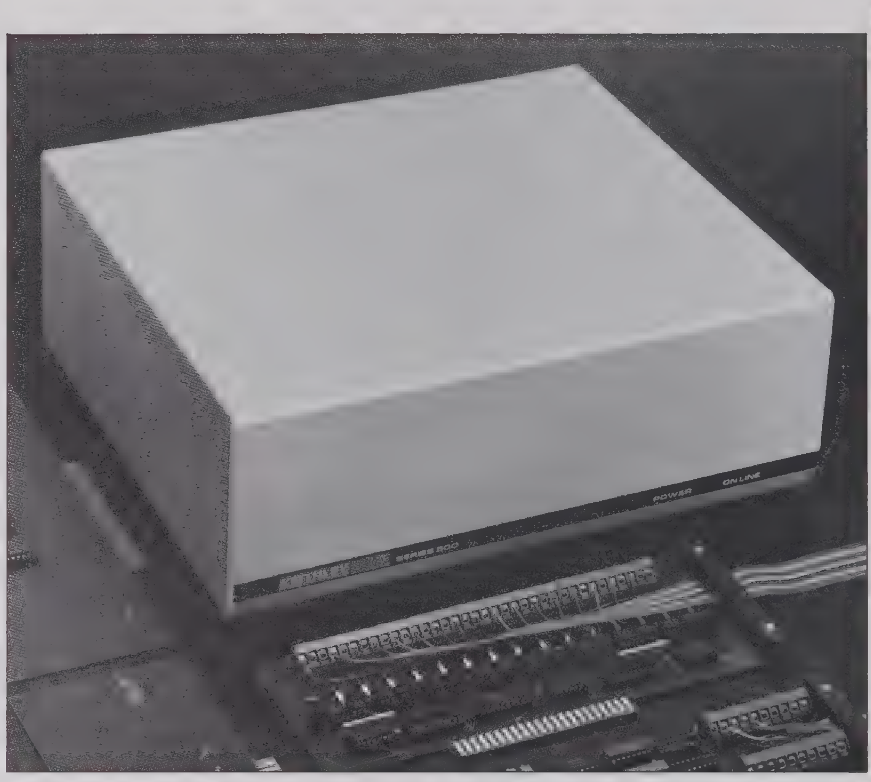

Integrated signal conditioning:
amplification, filtering, cold junction
compensation, excitation,
linearization, isolation.

Direct Transducer Connection

FIGURE 7: Intelligent Data Acquisition System Architecture



Scientific Workstation



A complete scientific workstation consists of a host personal computer, a Keithley Series 500 data acquisition and control system, and the Soft500 software package. With the Series 500, you have your choice of the most widely used and supported personal computers on the market.

At the heart of each of our systems is a rugged aluminum-cased card cage with a built-in non-switching dc power supply and ten slots for the installation of I/O modules. Every preconfigured system starts with basic analog input and A/D conversion—either 12-bit or 14-bit—with some systems adding flexible digital I/O. From this starting point, you can add modules for thermocouple input, analog output, isolated analog input, pulse counting, and other capabilities to configure the system that meets your requirements. There are no tricks to configuring the Series 500—just plug in the modules, connect your signals, and you're ready to go.

The **Systems 501** and **502** provide starting points for configuring 12-bit and 14-bit measurement systems to meet your needs. The **System 501** includes 8 single-ended analog inputs with 12-bit A/D resolution, along with 32 channels of digital input/output. In the System 501 and and every other starting system, software-controlled gains of ×1, ×2, ×5, and ×10 may be applied to any analog input signal in the system, maximizing each channel's conversion resolution. The TTL-compatible I/O may be configured in banks of 8 channels as either input or output, providing full flexibility for detecting contact closures, parallel communications, and trigger signals, as well as controlling switches, digital handshaking lines, and other binary functions.

The **System 502** offers enhanced analog measurement capabilities, with 16 single-ended or 8 differential analog inputs converted with true 14-bit resolution, together with 32 channels of TTL-compatible digital input/output. Local amplification of ×1, ×10, or ×100 is provided to supplement the ×1, ×2, ×5, and ×10 programmable gains for the analog input channels. As with every starting system , the Systems 501 and 502 include the Soft500 data acquisition software package, interface card and cable to the host PC, and complete hardware/software documentation, along with plenty of room to grow. The System 501 leaves 8 baseboard slots free for expansion and specialization, and the System 502 leaves 7 slots for you to fill as you wish, when you wish.

Whatever system you choose, there's one important thing to remember: Versatility. No matter how your needs change, the modular construction of the Keithley Series 500 family leaves you many more choices for the future.

COMPATIBILITY

The following computers are compatible with the Series 500 and System 570 hardware: IBM PC, IBM PC/XT, IBM PC/AT, Compaq Portable, Compaq Plus Portable, Compaq DeskPro 286, AT&T 6300, AT&T 6300+, Leading Edge Model D, NCR PC6, NCR PC8, Sperry IT, Zenith 158, and Zenith 240. For companies not list please contact the factory.

These PCs are available with a wide variety of disk drives, memory cards, video adapters, and other accessories. A limited number of configurations enable you to take full advantage of the System 570 and SOFT500. The following information summarizes these configurations.

For IBM PC, XT, and AT:

Recommended DOS: IBM PC-DOS 3.1 or later
Minimum/Recommended RAM: 512/640
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk
Video Adapter: IBM Color Graphics Adapter, IBM Enhanced Graphics, or Hercules Color Card

Notes: Compatible with 6MHz and 8MHz ATs

For Compaq Portable, Portable Plus, and Deskpro 286

Recommended DOS: Compaq DOS 3.0 or later
Minimum/Recommended RAM: 512/640
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk
Video Adapter: Built-in dual-mode Text-and-Graphics adapter

Notes: Compatible with Deskpro at both 6MHz and 8MHz. When installed for 6MHz, SOFT500 Version 5.0 should not be run at 8MHz, and vice versa.

For 100% IBM Compatible XT and AT Types:

Recommended DOS: Microsoft MS-DOS 3.0 or later
Minimum/Recommended RAM: 512/640
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk
Video Adapter: IBM Color Graphics Adapter, IBM Enhanced Graphics Adapter, or 100%-compatible video adpaters.

Notes: Compatible with AT-type compatibles at both 6MHz and 8MHz. When installed for 6MHz, SOFT500 Version 5.0 should not be run at 8MHz, and vice versa.

Notes on PC Configurations

1. We have successfully used AST, Quadram, and Persyst boards for memory expansion on IBM PC, XT, AT, and Compaq Portable computers.
2. SOFT500 requires a minimum of 512K RAM to load and run. 640K provides maximum data storage during acquisition and is recommended.
3. Installation of the optional 8087 or 80287 coprocessor increases the speed of execution of SOFT500 commands handling graphics and data arrays.
4. SOFT500 software requires an IBM Color Graphics Adapter, IBM Enhanced Graphics Adapter, or Hercules Color Card (not Hercules Monochrome Graphics) for display of SOFT500 graphics. Other graphics adapters may cause problems. Graphics adapters which make non-standard use of the computer's non-maskable interrupt will not work with SOFT500.
5. The IBM Enhanced Graphics Adapter (EGA) can be used with or without the EGA video memory expansion (256K total video memory).

INTERFACE REQUIREMENTS: One full length slot in PC.

SLOT/CHANNEL CAPACITY: Ten slots for optional modules; channel capacity is a function of the modules selected.

POWER: Switch selectable 105-125VAC or 210-250VAC. 50 or 60Hz, 100W maximum.

DIMENSIONS, WEIGHT: 111mm high × 308mm wide × 269mm deep ($4\frac{3}{8}$ in. × $12\frac{1}{8}$ in. × $10\frac{13}{32}$ in.). Net weight 4.8kg (10 lbs. 12 oz.).

OPTIONAL SOFTWARE: Quick500, RTMDS, DADiSP I, DADiSP II, Lab I/O, ASYST, ASYSTANT+, Labtech Notebook, Labtech RTA.

MODEL:	**DESCRIPTION**
500-500	System 500 (IBM and 100% Compatibles) Includes mainframe, interface, cable, Soft500 software, and documentation.
500-501:	System 501 (IBM and 100% Compatibles) Includes mainframe, interface, cable, 500-AMM1, 500-DIO1, Soft500 software, and documentation.
500-502:	System 502 (IBM and 100% Compatibles) Includes mainframe, interface, cable, 500-AIM1, 500-ADM2, 500-DIO1, Soft500 software, and documentation.

System 570

Data Acquisition Workstation

The System 570 is a personal computer based Data Acquisition Workstation that is priced like a board, but has features of a system. The 570 consists of both an interface card for your PC and an external module that allows easy connections and sensitive measurements away from the noisy PC environment.

Extensive signal capacity for both measurement and control is standard. Like a system, the 570 is expandable, accepting any one of 20 optional modules with varied I/O capabilities. Keithley's basic Soft500 software is included, and the 570 also works with other popular software packages.

Standard Hardware. The System 570 performs seven essential measurement and control functions: 12-bit 31kHz A to D conversion, programmable gain, 32 single-ended or 16 differential analog inputs, two channels of 12-bit analog output, 16 digital inputs, 16 digital outputs, and 16 power control lines.

Optional Modules. Any one of 20 modules from Keithley's Series 500 library may be plugged into the System 570's expansion slot to increase input/output channel capacity or to custom-tailor the analog inputs for specific signal conditioning needs.

Standard Software. The System 570 is supported by the same powerful Keithley Soft500 Data Acquisition and Control software that supports the Series 500. Soft500 is compatible with the IBM family of personal computers including the PC, XT, and AT, as well as most 100% compatibles.

KEITHLEY
SYSTEM 570
POWER
ON LINE

Other Software. Like the Series 500, the System 570 operates with optional and third-party software including:

- DADiSP I (Data Acquisition and Digital Signal Processing)
- DADiSP II with window-driven display, analysis, and data file import and export
- ASYST or ASYSTANT+ from Macmillan Software
- Labtech Notebook from Laboratory Technologies
- Lab I/O

System Solution. Now there is a choice besides a board that does too little or a box that costs too much. The unique System 570 is the complete measurement and control solution, with proven hardware and software for your measurement and control applications.

System 570

Data Acquisition Workstation

ANALOG INPUT

CHANNEL CAPACITY: 32 single ended or 16 differential inputs referred to ground, switch selectable.

INPUT IMPEDANCE: >100MΩ in parallel with 1000pF.

INPUT PROTECTION: Power on, 25V peak; power off, 10V peak.

COMMON MODE REJECTION RATIO: >80dB @ 60Hz, 1kΩ imbalance.

FULL SCALE INPUT: 12 ranges, ±2.5mV to ±10V.

GAIN SELECTIONS:

Instrumentation Amplifier (IA):	×1, ×10, ×100, switch selectable
Programmable Gain Amplifier (PGA):	×1, ×2, ×5, ×10, software selectable
A/D Converter Ranges:	0 to +5V, 0 to +10V, ±2.5V, ±5V, ±10V, switch selectable

RESOLUTION: 12 bits (1 part in 4096).

INPUT NOISE: 30μV p-p typical, 0.1 to 10Hz.

DYNAMIC CHARACTERISTICS:

Maximum Sample Rate: 31.4k samples/second

Settling Time (to 0.01%):

Time:	IA Gain:
20μs	×1
20μs	×10
70μs	×100

NONLINEARITY: ±0.025% of full scale (±1 LSB).

ACCURACY: Adjustable to ±1 LSB/range (add ±0.01% of full scale/PGA change).

TEMPERATURE COEFFICIENT: ±50ppm of full scale/°C plus:

Offset:	IA Gain:
±35μV/°C ±0.1 LSB	×1
±10μV/°C ±0.1 LSB	×10
± 5μV/°C ±0.1 LSB	×100

NOTE: All amplifier specifications referred to input.
All specifications pertain to System 570 mainframe only.

ANALOG OUTPUT

CHANNEL CAPACITY: 2, single ended to ground.

OUTPUT RANGES: Switch selectable per channel, 0 to +5V, 0 to +10V, ±2.5V, ±5V, ±10V.

RESOLUTION: 12 bits, 1 part in 4096.

DYNAMIC CHARACTERISTICS:

Maximum Conversion Rate:	1ms, interrupt driven
Settling Time:	<100μs to 0.01% of full scale transition
Slew Rate:	>0.5V/μs

OUTPUT IMPEDANCE: <2Ω.

LOAD CHARACTERISTICS: 10kΩ minimum, 1000pF maximum, short circuit protected.

NONLINEARITY: ±1 LSB of full scale range.

ACCURACY: Adjustable to ±½ LSB/range.

TEMPERATURE COEFFICIENT:

Gain:	±20ppm/°C of FSR, unipolar ±25ppm/°C of FSR, bipolar
Offset:	±6ppm/°C of FSR, unipolar ±23ppm/°C of FSR, bipolar

DIGITAL INPUT

CHANNEL CAPACITY: 16 non-isolated.

INPUT RANGE: TTL compatible, high true.

HIGH LEVEL CURRENT: 20μA.

LOW LEVEL CURRENT: −0.4mA.

DIGITAL OUTPUT

CHANNEL CAPACITY: 16 non-isolated.

OUTPUT RANGE: TTL compatible, high true.

DRIVE CAPABILITY: 10 TTL loads, 24mA sink at 0.5V.

POWER CONTROL

CHANNEL CAPACITY: 16 non-isolated.

OUTPUT RANGE: TTL compatible, low true.

DRIVE CAPABILITY: For use with optional solid state relays, extension cable, and mounting board (PCM3).

GENERAL

COMPATIBILITY: Same as Series 500.

HOST COMPUTER: IBM PC, PC XT, PC AT with IBM PC DOS Version 3.1, and most 100% compatibles.

INTERFACE REQUIREMENTS: One full length PC slot.

POWER REQUIRED FROM PC: 5V dc at 2A maximum.

DIMENSIONS, WEIGHT: 71mm high × 257mm wide × 300mm deep (2¾ in. × 10 in. × 11¾ in.). Net weight 2.3kg (5 lbs.).

MODEL:	DESCRIPTION:
500-570	Includes System 570 (IBM and 100% Compatibles), Soft500 software, and documentation.
500-570D	Includes System 570 (IBM PC, XT only), DADiSP I, Soft500 software, and documentation
500-570R	Includes System 570, AIM8, RTMDS, Soft500 software, and documentation

Series 500 Module Library

FUNCTION	MODULES	PAGE
ANALOG INPUT: Low Level DC Inputs	AIM1*	109
	AIM3	110
	AIM5**	111
	AIM7	112
	AIM8	113
High Level DC Inputs	AMM1*	107
	AIM1*	109
	AIM2	109
	AIM3	110
	AIM4**	110
Carrier Amplifier	AIM9	114
Thermocouples: B, E, J, K, R, S, T	AIM5**	111
	AIM7	112
Strain Gage	AIM8	113
LVDT/RVDT	AIM9	114
RTD, 100Ω	AIM6	111
AD590 Temperature Sensors	AIM1*	109
	AIM3	110
	AIM5**	111
	AIM6	111
4-20mA Current Loop	AIM1*	109
	AIM2	109
	AIM3	110
	AIM4**	110
ANALOG TO DIGITAL CONVERSION: 12-Bit A/D and Analog Input	AMM1*	107
12-Bit A/D	ADM1*	108
14-Bit A/D	ADM2*	108
ANALOG OUTPUT: 12-Bit D/A	AOM1	115
16-Bit D/A	AOM2	115
0-20mA Current Loop	AOM3	116
0-10V Programmable Source	AOM4	116
DIGITAL INPUT/OUTPUT: 32-Channel Input/Output	DIO1	117
16-Channel Isolated Input	DIM1**	117
16-Channel Isolated Output	DOM1**	118
GRAPHICS ACCELERATOR	RTMDS	122
IEEE-488 CONTROLLER	GPIB	124
PULSE COUNTING: Frequency Input	PIM1	120
Event Counting	PIM2	120
POWER CONTROL: AC Power Control	PCM1	118
AC/DC Control and Sensing	PCM2	119
570 Power Control	PCM3	119
PROTOTYPING:	PROTO Board	121
	EXTEND Board	121
STEPPER MOTORS:	STEP1*, STEP2*	126

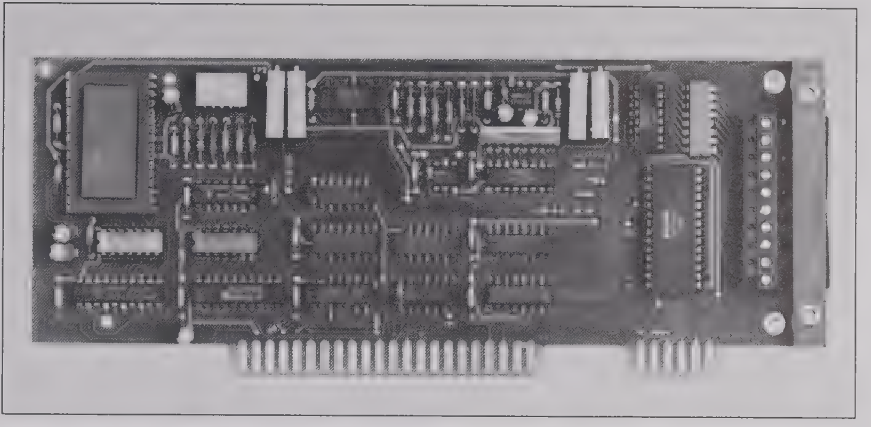
*Not for use in System 570. **Isolated Inputs

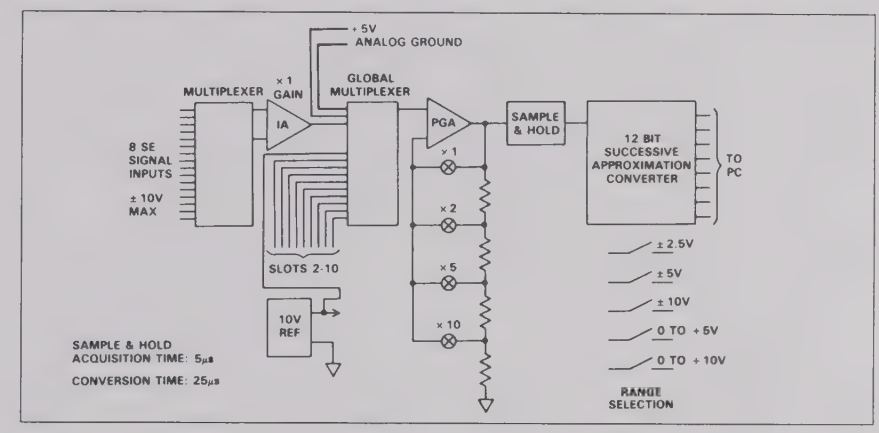
The master card for performing analog measurements with the Series 500 is the **Master Measurement Module 1 (AMM 1)**, which is necessary in all systems requiring analog input or analog-to-digital conversion. The AMM1 combines two important Series 500 functions in a single module: performing analog signal conditioning and switching as well as A/D conversion.

The analog section of the module provides signal selection and programmable gain for both local and global analog signals connected to the Series 500. After analog conditioning, signals are routed to the A/D converter section of the module for the analog-to-digital conversion process.

The AMM1 offers 8 local single-ended inputs with unity (×1) local gain. Input signals are applied through on-card screw terminals. Global conditioning is accomplished through a high-speed, software-controlled gain amplifier with programmable ×1, ×2, ×5, and ×10 gain values. Since all analog inputs connected to the Series 500 pass through the global circuitry, these gain values can be applied to any analog input in the system.

For A/D conversion, the AMM1 uses a 12-bit successive approximation converter that provides fast, accurate measurement and conversion. A maximum conversion time of only 25μs and a sample-and-hold acquisition time of 5μs allow sampling rates as high as 31.4kHz.





To maximize resolution, the AMM1 has five A/D converter ranges (three bipolar, two unipolar) that can be selected by on-card DIP switches. The AMM1 is designed to be used only in slot 1 of the system baseboard.

INPUT CHANNELS

Local: 8 single-ended.

Global: 9 inputs from slots 2-10.

GLOBAL PROGRAMMABLE GAIN AMPLIFIER

Software Programmable Gains: ×1, ×2, ×5, ×10.

Input Range: ×1, ±10V; ×2, ±5V; ×5, ±2V; ×10, ±1V.

Accuracy: ±(0.01% + 50μV).

Non-Linearity: ±0.005% of full scale.

Temperature Coefficient: ±(0.001% + 20μV)/°C.

Input Noise Voltage: 30μV p-p, 0.1Hz to 10kHz.

Settling Time (to 0.01%): 6μs.

Small Signal Bandwidth: 280kHz.

ANALOG-TO-DIGITAL CONVERTER

Resolution: 12 bits, 1 part in 4096.

Input Ranges: ±2.5V, ±5V, ±10V, 0 to +5V, 0 to +10V.

Nonlinearity: ±0.025% (±1 lsb).

Nonlinearity Temperature Coefficient: ±0.003%/°C.

Accuracy (including nonlinearity): ±(0.03% + 1 lsb).

Accuracy Temperature Coefficient: ±(0.0035% ± 0.11 lsb)/°C.

Sample-and-Hold Acquisition Time: 5μs.

Conversion Time: 25μs max.

GLOBAL 10.000V REFERENCE

Accuracy: ±0.01%.

Temperature Coefficient: ±0.002%/°C.

Load Current: 10mA max.

Noise: 20μV p-p, 0.1Hz to 10Hz; 10μV rms, 10Hz to 30kHz.

NOTE: All amplifier specifications are with respect to input.

ADM1, ADM2/A/D Conversion Modules

12-Bit, 14-Bit

The **Analog-to-Digital Module 1 (ADM1)** is a 12-bit successive approximation A/D converter with 25 microsecond conversion time and 5 microsecond sample-and-hold. The maximum sampling speed on one channel is 31.4kHz, including software overhead. The ADM1 provides true 12-bit accuracy and monotonocity, with non-linearity of ±½ lsb.

An ADM1 module is used in conjunction with an AIM1 Analog Input Module in slot 1. If an AMM1 is used rather than an AIM1, the ADM1 is not required since the AMM1 module already contains a 12-bit A/D converter.

The ADM1 receives conditioned signals from all analog input channels via the global circuitry in the AIM1 or AMM1. Analog signals are resolved across a full-range scale of 4096 discrete steps. To maximize A/D resolution, five A/D ranges (0 to +5V and 0 to +10V unipolar; ±2.5V, ±5V, and ±10V bipolar) can be selected by on-card DIP switches. Range selection supplements the signal conditioning available on the AIM modules and provides flexibility in connecting various signal types.

The ADM1 module may be used on its own or with the ADM2 14-bit module, for applications requiring different resolutions. When a single ADM module is used, it should always be placed in slot 2 of the Series 500 baseboard. If a second ADM module is installed, it should be placed in slot 3 of the baseboard; slot 1 must contain an Analog Input Module (AIM1).

INPUT CHARACTERISTICS

Input Ranges (switch selectable): ±2.5V, ±5V, ±10V, 0 to +5V, 0 to +10V.

Resolution: 12 bits.

Nonlinearity: ±0.012% (±½ lsb).

Nonlinearity Temperature Coefficient: ±0.0003%/°C.

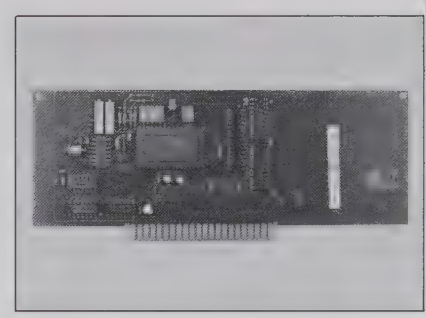
Accuracy (including non-linearity): ±(0.03% + 1.0 lsb)/°C.

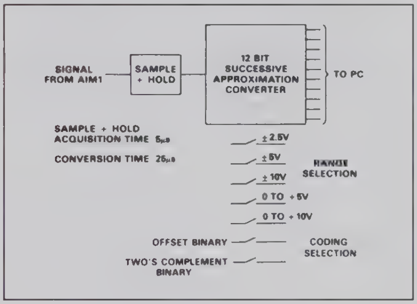
Accuracy Temperature Coefficient: ±(0.0035% + 0.1 lsb)/°C.

DYNAMIC PERFORMANCE

Sample-and-Hold Acquisition Time: 5 microseconds.

Conversion Time: 25 microseconds maximum.




SIGNAL FROM AIM1
SAMPLE + HOLD
12 BIT SUCCESSIVE APPROXIMATION CONVERTER
TO PC
SAMPLE + HOLD ACQUISITION TIME 5μs
CONVERSION TIME 25μs
±2.5V
±5V
±10V
0 TO +5V
0 TO +10V
RANGE SELECTION
OFFSET BINARY
TWO'S COMPLEMENT BINARY
CODING SELECTION

The **High Resolution Analog-to-Digital Module 2 (ADM2)** is a 14-bit successive approximation A/D converter designed for applications requiring high resolution. It offers a conversion time of 35 microseconds and sample-and hold time of 4 microseconds. Analog signals are resolved across a full-scale range of 16,384 steps. To maximize A/D resolution, four A/D ranges (0 to +5V and 0 to +10V unipolar; ±5V and ±10V bipolar) can be selected by on-card DIP switches. Range selection supplements the signal conditioning available on the AIM or AMM modules and provides flexibility in connecting various signal types.

The ADM2 module may be used on its own or with the ADM1 or AMM1 12-bit module, for applications requiring different resolutions. When a single ADM module is used, it should always be placed in slot 2 of the Series 500 baseboard. If a second ADM module is installed, it should be placed in slot 3 of the baseboard; slot 1 must contain an Analog Input Module (AIM1) or Analog Measurement Module (AMM1).

INPUT CHARACTERISTICS

Input Ranges (switch selectable): ±5V, ±10V bipolar; 0 to +5V, 0 to +10V unipolar.

Resolution: 14 bits.

Nonlinearity: ±0.006% (±1 lsb).

Nonlinearity Temperature Coefficient: ±0.0002%/°C.

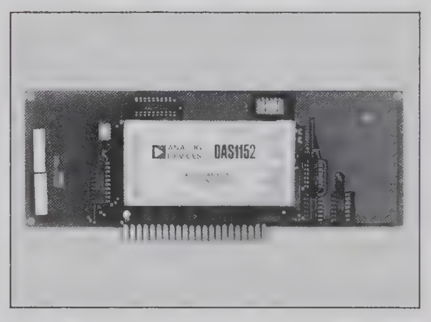
Accuracy (including non-linearity): ±(0.008% + 1.0 lsb)/°C.

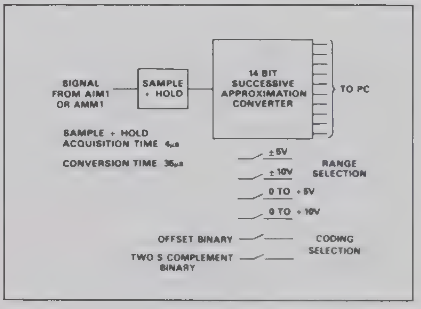
Accuracy Temperature Coefficient: ±(0.001% + 0.15 lsb)/°C.

DYNAMIC PERFORMANCE

Sample-and-Hold Acquisition Time: 4 microseconds maximum.

Conversion Time: 35 microseconds maximum.




SIGNAL FROM AIM1 OR AMM1
SAMPLE + HOLD
14 BIT SUCCESSIVE APPROXIMATION CONVERTER
TO PC
SAMPLE + HOLD ACQUISITION TIME 4μs
CONVERSION TIME 35μs
±5V
±10V
0 TO +5V
0 TO +10V
RANGE SELECTION
OFFSET BINARY
TWO S COMPLEMENT BINARY
CODING SELECTION

Analog Input Modules/**AIM1, AIM2**

Master Analog Input, High Level

In some systems the **Master Analog Input Module 1 (AIM1)** is used with the ADM1 or ADM2 as the master card in the analog-to-digital subsystem. All systems with analog inputs require either the AIM1 or AMM1. The AIM1 provides conditioning for signals connected to the screw terminals on the AIM1 board itself (local) as well as for all analog signals coming from other Analog Input Modules in the system (global).

The AIM1 offers 16 channels of single-ended analog input or 8 channels of differential input, with switch-selectable gains of ×1, ×10, and ×100 for the direct connection of low-level analog signals. These gains are applied to signals received by the AIM1 card itself. Signals received by all other Analog Input Modules in the system are routed to the AIM1 card for programmable amplification, then on to the A/D converter in slot 2 or 3. This global signal conditioning is provided by a high-speed programmable gain amplifier which offers four software-controlled gain steps of ×1, ×2, ×5, and ×10.

Measurement and signal conditioning parameters on the AIM1 are determined by the settings of four switches and the values of various optional user-installed resistors.

The AIM1 must be installed in slot 1 of the Series 500 baseboard. All local channels are connected directly to on-card screw terminals.

INPUT CHANNELS

Global: 8 inputs from slots 3-10.

Local: 8 differential or 16 single-ended.

INPUT CHARACTERISTICS: GLOBAL PROGRAMMABLE GAIN AMPLIFIER

Software Programmable Gains: ×1, ×2, ×5, ×10.

Input Ranges: ×1, ±10V; ×2, ±5V; ×5, ±2V; ×10, ±1V.

Accuracy: ±(0.01% + 50μV).

Nonlinearity: ±0.005% of full scale.

Temperature Coefficient: ±(0.001% + 20μV)/°C.

Input Noise Voltage: 30μV p-p, 0.1Hz to 10kHz.

Settling Time (to 0.01%): 6μs.

Slew Rate: 10V/μs.

Small Signal Bandwidth: 280kHz.

INPUT CHARACTERISTICS: LOCAL INSTRUMENTATION AMPLIFIER

Switch Selectable Gains: ×1, ×10, ×100.

Input Ranges: ×1, ±10V; ×10, ±1V; ×100, ±100mV.

Input Protection: ±30V max. (powered), ±10V max. (unpowered).

Accuracy: ×1, ±(0.01%+20μV); ×10 and ×100, ±(0.01%+10μV).

Temperature Coefficient: ×1, ±(0.001%+10μV)/°C; ×10, ±(0.002%+4μV)/°C; ×100, ±(0.002%+2μV)/°C.

Common Mode Rejection Ratio: >80 dB, dc to 60Hz.

Input Bias Current: <1nA.

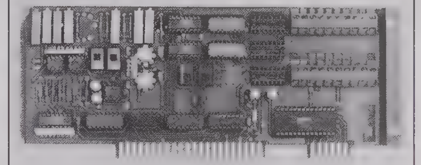
Input Resistance: >100MΩ.

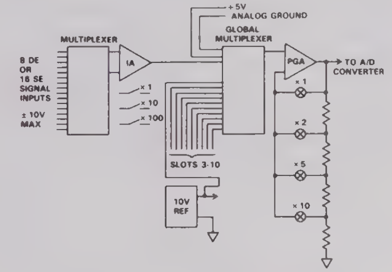
Input Noise Voltage: 5μV p-p, 0.1Hz to 10Hz; 10μV rms, 10Hz to 30kHz.

Settling Time (to 0.01%): ×1, 15μs; ×10, 30μs; ×100, 75μs.

Slew Rate (×1): 10V/μs.

Small Signal Bandwidth: 130kHz.





GLOBAL 10.000 VOLT REFERENCE

Accuracy: ±0.01%.

Temperature Coefficient: ±0.002%/°C.

Load Current: 10mA max.

Load Regulation: ±0.005%/mA.

Noise: 20μV p-p, 0.1Hz to 10Hz; 10μV rms, 10Hz to 30kHz.

NOTE: All amplifier specifications with respect to input.

The **High-Level Analog Input Module 2 (AIM2)** is the most cost-effective way of providing a large number of analog input channels. The AIM2 card offers 32 channels of analog input, and is designed to accept ±10V full scale signals. Two high-speed multiplexers, controlled from software, select the channel to be measured. A multiplexer settling time of 4μs preserves system throughput.

From the AIM2 module, signals are routed to the AIM1 or AMM1 in slot 1 of the Series 500 baseboard, via a private low-noise analog pathway. At the AIM1 or AMM1 module, gain is applied and the signals are directed to the A/D converter.

Optional resistor locations permit the installation of path-to-ground resistors. All signal connections are made directly to on-card screw terminals. The AIM2 module may be installed in slots 2-10 of the system baseboard.

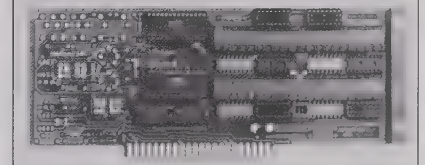
INPUT CHARACTERISTICS

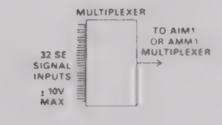
Input Channels (Local): 32.

Input Range: ±10V.

Input Protection: ±30V max. (powered), ±10V max. (unpowered).

Input Current: <1nA.





AIM3, AIM4/Analog Input Modules

High Sensitivity, Isolated High Level

The **High Sensitivity Analog Input Module (AIM3)** accepts signals from ±100mV to ±10V full scale, and offers either 32 channels of single-ended input or 16 channels of differential input. The selection of single-ended or differential input is made by setting on-card switches.

The AIM3 module provides high-speed multiplexing, gain amplification of ×1, ×10, or ×100. All systems with analog inputs require either the AIM1 or AMM1. Signals from the AIM3 are routed along a private low-noise pathway to the conditioning circuitry of the AIM1 or AMM1, where programmable gain up to ×10 can be applied prior to A/D conversion.

With the installation of optional resistors, the AIM3 module can be modified to accept current inputs, or to provide a current path to ground when using thermocouples. In addition, a guard terminal is provided for the connection of signal shields to lower noise along input lines. All signals are connected directly to on-card screw terminals. The AIM3 module may be placed in slots 2-10 of the Series 500 baseboard.

INPUT CHARACTERISTICS

Input Channels (Local): 16 differential or 32 single-ended.

Switch Selectable Gains: ×1, ×10, ×100.

Input Ranges: ×1, ±10V; ×10, ±1V; ×100, ±100mV.

Input Protection: ±30V max. (powered), ±10V max. (unpowered).

Accuracy: ×1, ±(0.01%+20μV); ×10 and ×100, ±(0.01%+10μV).

Nonlinearity: 0.005% of full scale.

Temperature Coefficient: ×1, ±(0.001%+10μV)/°C; ×10, ±(0.002%+4μV)/°C; ×100, ±(0.002%+2μV).

Common Mode Rejection Ratio: >80dB, dc to 60Hz.

Input Bias Current: <1nA.

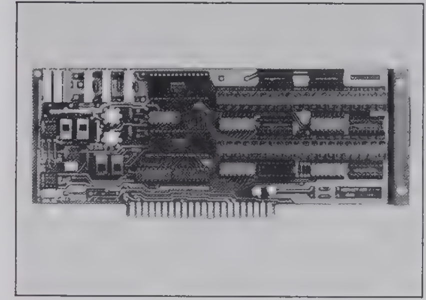
Input Resistance: >100MΩ.

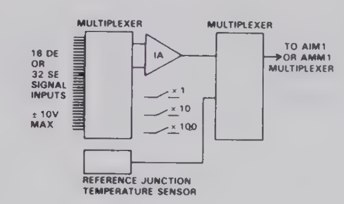
Input Noise Voltage: 5μV p-p, 0.1Hz to 10Hz; 10μV rms, 10Hz to 30kHz.

Settling Time (to 0.01%): ×1, 15μs; ×10, 30μs; ×100, 75μs.

Small Signal Bandwidth: 130kHz.

Reference Junction Sensor: Output: 100mV/°C. Accuracy: ±0.25°C. Temperature Coefficient: 0.1°C/°C.




MULTIPLEXER
MULTIPLEXER
16 DE OR 32 SE SIGNAL INPUTS
± 10V MAX
IA
× 1
× 10
× 100
TO AIM1 OR AMM1 MULTIPLEXER
REFERENCE JUNCTION TEMPERATURE SENSOR

The **Isolated High-Level Analog Input Module 4 (AIM4)** is ideal for use in applications involving high common mode voltages of over 10V between channels. The AIM4 provides isolation and signal conditioning for four channels of voltage input from ±50mV to ±5V or current loop input with an external resistor. Because the input channels are completely isolated from other channels and from the system ground, the AIM4 module can accept signals with common mode voltages as high as +500V, and provides protection to ±130V (normal mode). Channel-to-channel isolation is 500V. All systems with analog inputs require either the AIM1 or AMM1.

The AIM4 module provides switch-selected gains of ×1 or ×100. By changing resistor and potentiometer values, individual local gains can be selected for each channel. From the AIM4 module, signals are routed along a private, low-noise pathway to the conditioning circuitry of the AIM1 or AMM1, where programmable gain up to ×10 can be applied prior to A/D conversion.

The AIM4 module may be installed in slots 2-10 of the system baseboard.

INPUT CHARACTERISTICS

Input Channels (Local): 4 (isolated from each other and ground).

Gain: ×1 or ×100 (user-configurable for other gains with optional resistor).

Input Range: ×1, ±5V max.; ×100, ±50mV max.

Accuracy: ×1, ±0.2%; ×100, ±0.2% adjustable to 1 lsb.

Gain Nonlinearity: ±0.02% max.

Input Offset: ±50μV max., adjustable to 0.

Output Offset: ±12mV max., adjustable to 0.

Temperature Coefficient: ×1, ±0.0025%/°C. ×100, ±0.0050%/°C.

Temperature Coefficient Input Offset: ±5μV/°C.

Temperature Coefficient Output Offset: ±50μV/°C.

Input Noise Voltage: 1μV p-p, 0.001Hz to 100kHz, $R_s < 1k\Omega$.

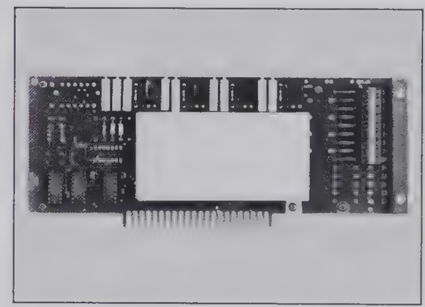
Input Bias Current: +8nA max.

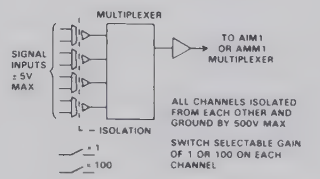
Input Resistance: 100MΩ.

Protection: 130V rms max. normal mode, f ≤ 60Hz.

Isolation: 500V peak channel-to-channel or channel-to-ground.

Common Mode Rejection: 145dB, ×100, $R_s < 100\Omega$, f ≤ 60Hz.




MULTIPLEXER
SIGNAL INPUTS ± 5V MAX
TO AIM1 OR AMM1 MULTIPLEXER
ALL CHANNELS ISOLATED FROM EACH OTHER AND GROUND BY 500V MAX
– ISOLATION
× 1
× 100
SWITCH SELECTABLE GAIN OF 1 OR 100 ON EACH CHANNEL

Normal Mode Rejection: 55dB, ×100, f ≥ 50Hz.

Settling Time (after channel selection): 2.5ms to 0.01% assuming settled input.

Analog Input Modules/**AIM5, AIM6**

Isolated Low Level, RTD

The **Isolated Low-Level Analog Input Module 5 (AIM5)** is optimized for use in environments where there is a high level of noise on the lines, and/or voltages higher than ±10V between channels. The AIM5 is designed to accept signals from ±5mV to ±50mV, including signals from thermocouples. Isolated input permits the connection of signals with high common mode voltages—up to 500V dc or peak ac—and provides normal mode protection up to 130V. Channel-to-channel isolation is 500V dc or peak ac. The input bandwidth is below 2Hz, reducing sensitivity to 50/60 cycle ac noise.

There are four input channels on the AIM5 module, each with individually adjustable gain amplification. The module is shipped from the factory with a preset gain of ×100, appropriate for thermocouple types B, E, J, K, R, S, and T. This gain can be reset for each channel by changing the value of the gain-setting resistor. All systems with analog inputs require either the AIM1 or AMM1.

From the AIM5, signals are routed via a private, low noise analog pathway to the AIM1 or AMM1 for conditioning prior to A/D conversion. An additional programmable gain of up to ×10 can be applied.

The AIM5 module may be placed in slots 2-10 of the Series 500 baseboard.

INPUT CHARACTERISTICS

Input Channels (Local): 4 (isolated from each other and ground).

Gain: ×100 (user-configurable for other gains with optional resistor).

Input Range: ±50mV max.

Accuracy: Gain: ±0.2%, adjustable to 1 lsb. Gain Linearity: ±0.02% max. Input Offset: ±20μV max., adjustable to 0. Output Offset: ±12mV max., adjustable to 0.

Temperature Coefficient: Gain: ±0.005%/°C. Input Offset: ±2.5μV/°C. Output Offset: ±50μV max.

Input Bias Current: +8nA max.

Input Resistance: 100MΩ.

Input Noise Voltage: 1μV p-p, 0.01Hz to 100Hz. $R_s < 1\text{k}\Omega$.

Protection: 130V rms max. normal mode.

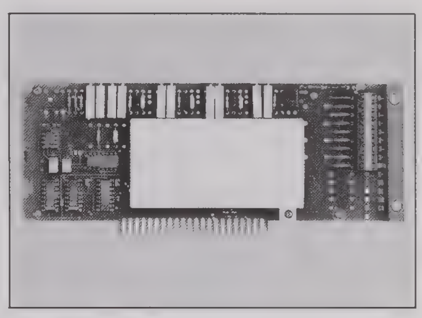
Isolation: 500V peak channel-to-channel or channel-to-ground.

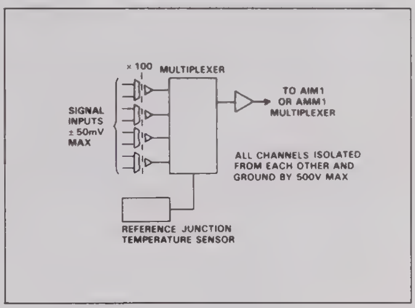
Common Mode Rejection: 130dB, $R_s < 100\Omega$, $f \leq 60\text{Hz}$.

Normal Mode Rejection: 55dB, $f \geq 50\text{Hz}$.

Settling Time (after channel selection): 2.5ms to 0.01%, assuming settled input.

Reference Junction Sensor: Output: 100mV/°C. Accuracy: ±0.25%. Temperature Coefficient: 0.1°C/°C.




× 100
MULTIPLEXER
SIGNAL INPUTS ± 50mV MAX
TO AIM1 OR AMM1 MULTIPLEXER
ALL CHANNELS ISOLATED FROM EACH OTHER AND GROUND BY 500V MAX
REFERENCE JUNCTION TEMPERATURE SENSOR

The **RTD Analog Input Module 6 (AIM6)** provides appropriate excitation, bridge detection, and amplification for signals from 100Ω platinum RTDs and AD590/AC2626 semiconductor temperature sensors. Four input channels are provided, accommodating any combination of these devices.

The AIM6 module can accept common mode voltages up to ±6V. Optional resistors convert current output to voltage output for the connection of AD590 and AC2626 temperature sensors.

All systems with analog inputs require either the AIM1 or AMM1. From the AIM6 module, signals are routed along a private, low-noise pathway to the conditioning circuitry of the AIM1 or AMM1, where programmable gain up to ×10 can be applied prior to A/D conversion.

The AIM6 module may be installed in slots 2-10 of the system baseboard.

INPUT CHARACTERISTICS

Input Channels (Local): 4.

Gain: ×50 (RTD, AD590/AC2626).

Input Range: ×50, ±100mV max.

Accuracy: Gain: ×50, ±0.6%, adjustable to 1 lsb. Gain Nonlinearity: ±0.01% max. Offset: ±150μV max., adjustable to 0 (RTD).

Temperature Coefficient: Gain: ×50, ±0.0025%/°C. Input Offset: ±1μV/°C.

Input Noise Voltage: 1.5μV p-p, 0.01Hz to 100Hz, $R_s < 1\text{k}\Omega$.

Input Bias Current: 10nA max.

Input Resistance: 20MΩ.

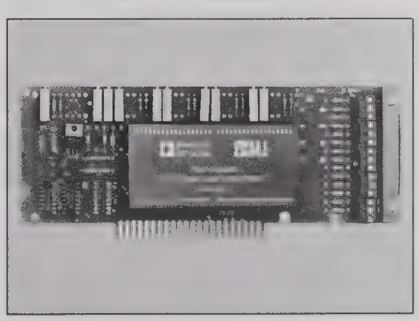
Protection: 130V rms max. normal mode, $f \leq 60\text{Hz}$.

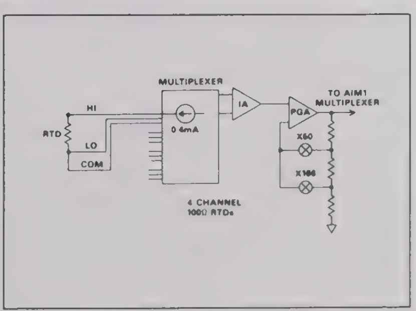
Common Mode Voltage: ±6V peak.

Common Mode Rejection: 94dB, $R_s = 100\Omega$.

Normal Mode Rejection: 22dB, $f \geq 50\text{Hz}$.

Settling Time: 0.4s to 0.01%.





AIM7/Analog Input Module

Thermocouple

The **Thermocouple Analog Input Module (AIM7)**, with its cold-junction reference circuitry, is optimized for the direct connection of thermocouple types B, E, J, K, R, S, and T (in any combination). The AIM7 accepts signals from −100mV to +100mV, and offers 16 channels of differential input. An isothermal block provides the signal connections.

The AIM7 module provides high-speed multiplexing, with a multiplexer settling time of 2.2ms. The module offers a fixed instrumentation amplification of ×100, and cold junction reference circuitry for the direct connection of thermocouples. All systems with an AIM7 require either the AIM1 or AMM1. Signals from the AIM7 are routed along a private, low noise analog pathway to the conditioning circuitry of the AIM1 or AMM1, where programmable gain of up to ×10 can be applied prior to A/D conversion.

With an input bandwidth of 1kHz, the AIM7 has reduced sensitivity to 50/60 cycle ac noise. This increases the accuracy of readings obtained with this module.

The AIM7 module may be placed in slots 2-10 of the Series 500 baseboard.

INPUT CHARACTERISTICS

Input Channels (Local): 16 differential.

Fixed Gain: ×100.

Input Range: ±100mV.

Input Protection: ±15V max. (powered), ±10V max. (unpowered).

Accuracy: ±(0.01% + 10μV).

Nonlinearity: 0.005% of full scale.

Common Mode Rejection Ratio: >90dB, dc to 60Hz.

Bandwidth: 1kHz.

Settling Time (to 0.01%): 2.2ms.

Offset Temperature Coefficient: 2μV/°C.

Input Noise Voltage: 1μV p-p max., 0.1Hz to 10Hz; 2μV p-p max., 10Hz to 30kHz.

Reference Junction Sensor: Output: +100mV per °C. Accuracy: ±0.25°C. Temperature Coefficient: 0.1°C/°C.

System Resolution*:

PGA = 2, ADM1 on 0 to +10V Range: 12μV/count, 0.3°C/count.

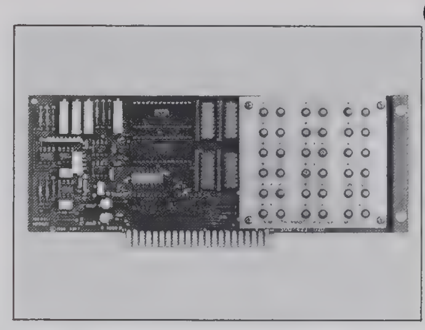
PGA = 2, ADM2 on 0 to +10V Range: 3μV/count, 0.075°C/count.

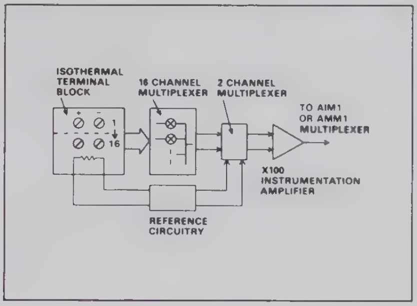
PGA = 10, ADM2 on −5 to +5V Range: 0.6μV/count, 0.015°C/count

*Typical resolution using type J, K, or T thermocouple, 0 to +400°C span (assume 40μV/°C).

Offset: Between sensor and any terminal: ±0.25°C max. Between any adjacent terminals: 0.1°C max.

NOTE: All amplifier specifications with respect to input.




ISOTHERMAL TERMINAL BLOCK
+
−
1
16
16 CHANNEL MULTIPLEXER
2 CHANNEL MULTIPLEXER
TO AIM1 OR AMM1 MULTIPLEXER
X100 INSTRUMENTATION AMPLIFIER
REFERENCE CIRCUITRY

THERMOCOUPLE MEASUREMENTS

When measuring multiple thermocouples, it is necessary to measure the temperature at the connection between the thermocouple and the instrument (this is called the cold junction temperature) in order to calculate the temperature value from the thermocouple's input. With many data acquisition systems, a single temperature sensor is usually employed to attain a cold junction reference temperature for all of the thermocouple inputs to the system. However, with the standard plastic screw terminal blocks, there may be a temperature gradient in excess of 5°C across the measuring channels. This may cause a significant error of a similar amount, depending on a channel's position relative to the cold junction sensor. In the AIM7, the terminal block itself is designed to be isothermal—that is, to maintain constant temperature throughout the block so that the sensor reads the actual cold junction value for all of the input channels. The result is that 16 thermocouples can be read on a single module, with no loss of accuracy from channel to channel. In addition, the AIM7 handles the low-level voltages from the thermocouple by including a fixed ×100 amplifier with low pass filtering to eliminate high-frequency noise that typically occurs on thermocouple signals.

Analog Input Module/**AIM8**

Strain Gage Analog Input Module

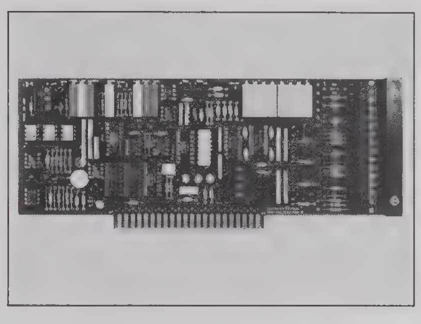
- **4 channel strain gage input with independent excitation per channel**
- **Programmable gains of ×1, ×10, ×100, and ×1000 with sensitivity below 5μV**
- **Zero suppresssion to increase effective dynamic range in low level dc measurements**
- **Full bridge, half bridge, and quarter bridge completion with 120Ω and 350Ω completion resistors included**

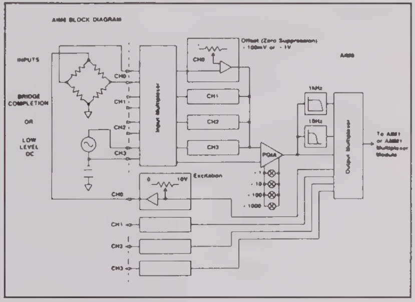
The **Strain Gage Analog Input Module 8 (AIM8)** is the most versatile module covering applications from general purpose and low level dc measurements to strain gage and strain gage based transducer applications. Each of the four channels has its own adjustable excitation, adjustable offset for transducer balance or dc signal zero suppression, and bridge completion facilities. The high gain differential input instrumentation amplifier allows for conventional dc signal measurements with program selectable low pass filtering from dc to 10Hz, 1kHz, or wideband (approximately 3kHz). By selecting the offset option, the dc amplifier not only allows for bridge balance with strain gages, but also can be applied as zero suppression (from 0 to ±100mV or ±1V) to small signals with large offset for dynamic signal expansion.

Unique to the AIM8 module is the programmable instrumentation amplifier with gains of ×1, ×10, ×100, and ×1000. Combine this with the system's programmable gain amplifier of ×1, ×2, ×5, or ×10, and the result is 13 software programmable ranges from 1 to 10,000 in a 1, 2, 5 sequence with the Series 500. The user may also select a 12-bit or 14-bit A/D converter.

All Series 500 Mainframe Systems with analog inputs require either the AMM1 or the AIM1 in slot 1. The AIM1 also requires a 12- or 14-bit A to D module in slot 2. From the AIM8 module, signals are routed along a private low-noise pathway to the conditioning circuitry of the AMM1 or AIM1, where programmable gain can be applied prior to A to D conversion.

The AIM8 module may be installed in slots 2-10 of the mainframe system or in the option slot of the System 570. To maximize analog signal accuracy, analog modules should be installed in the lower numbered slots of the mainframe system.





INPUT CHARACTERISTICS

Input Channels (Local): 4, differential and balanced to ground.

Gain Selection: Software selectable Instrumentation Amplifier Gain (PGIA): ×1, ×10, ×100, and ×1000.

Input Dynamic Range:		
	×1	± 10 V max
	×10	± 1 V max
	×100	±100 V max
	×1000	± 10mV max

Input Protection: ±15V max (powered)
±10V max (unpowered)

Input Impedance: 1MΩ in parallel with 1000pF, each input to common.

Common Mode Voltage: ±10V.

Common Mode Rejection: >90dB, dc to 60Hz.

Accuracy: ±(0.01% + 10μV).

Nonlinearity: 0.01% of full scale.

Bandwidth: Software selectable single pole filter (−3dB) dc to 10Hz, dc to 1kHz, and wideband (dc to 3kHz).

Settling Time (to 0.01%): 0.7ms wideband; 2.5ms @ 1kHz; 250ms @ 10Hz.

Noise: 2μV p-p. 0.1 to 10Hz.
4μV p-p, 10 to 1000Hz.

Temperature Coefficient: Gain: ±50ppm/°C. Offset (adjustable to zero): 4μV/°C @ ×1 PGIA; 2.5μV/°C @ ×10, ×100, and ×1000 PGIA.

BALANCE OR ZERO SUPPRESSION CHARACTERISTICS

Voltage Range: Jumper selectable off, ±100mV or ±1V; range or ground software selectable.

Balance: Manual, multiturn potentiometer per channel.

Temperature Coefficient: 2.5μV/°C on ±100mV; 5μV/°C on ±1V.

EXCITATION CHARACTERISTICS

Voltage Range: 0 to +10V, adjustable per channel and software readable.

Current: +100mA max per channel.

Protection: Short to ground, 20s max at full power.

Temperature Coefficient: 200ppm/°C.

Bridge Completion Facilities: Quarter, half, and full bridge.

SYSTEM RANGE AND RESOLUTION

Includes PGA of ×1, ×2, ×5, and ×10 plus PGIA of ×1, ×10, ×100, and ×1000 plus the unipolar and bipolar input ranges of the A to D converters.

12 Bit A to D Converter (Series 500 or System 570): 16 ranges from ±10V to ±250μV full scale; 4.88mV/bit to 122nV/bit*.

14 Bit A to D Converter (Series 500 only): 15 ranges from ±10V to ±500μV full scale; 1.22mV/bit to 61nV/bit*.

*NOTE: System noise level of 5μV p-p may prevent any practical use of the lower order bits.

Strain Gages

Strain gages are the most important transducers for mechanical measurements and structural testing. They are used to measure pressure, force, displacement, flow, and other physical properties. For example, a load cell (a particular use of strain gages) is directly calibrated in terms of weight.

The operating principle of a strain gage is simple:

Pressure or force ∝ Strain ∝ Change in resistance of the strain gage element

The strain gage is bonded to the structure that is being measured. Force applied to the structure makes the structure stretch or compress, depending on whether the force produces tension or compression. This strain is in turn transmitted to the bonded strain gage element, a foil resistor or a semiconductor crystal in the strain gage, and changes its resistance. This change in resistance can be directly related to the force applied.

Strain gages are available in different physical and electrical configurations, with various sensitivities, dynamic ranges, and temperature susceptibility, all to fit a wide range of applications. To accommodate the variety of strain gage types, the measuring circuit must be flexible: it must handle several bridge configurations, ¼, ½, and full; it must have variable excitation to avoid heating effects in the resistive elements; and it must have a wide range of gains and offsets. These characteristics were incorporated into the design of the AIM8.

AIM9/Analog Input Module

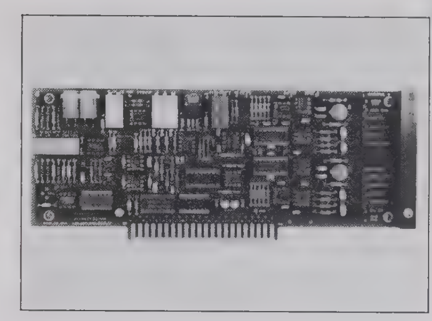
LVDT/RVDT Analog Input Module

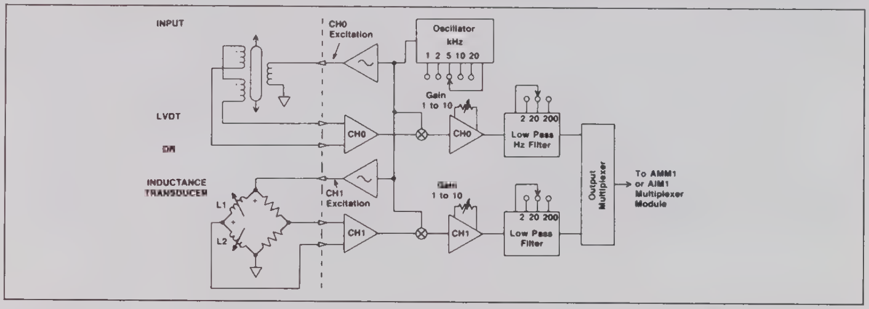
- **2 channel carrier amplifier for use with ac excited linear or rotary variable differential transformer (LVDT or RVDT) or variable inductance transducers**
- **5 selectable excitation frequencies: 1kHz, 2kHz, 5kHz, 10kHz, 20kHz**
- **3 software selectable 5-pole low pass filters of 2, 20, and 200Hz**

The **LVDT/RVDT Analog Input Module 9 (AIM9)** is a two channel specialized signal conditioner that provides the necessary ac excitation and phase sensitive demodulation required of transducers based on the principles of inductance and reluctance.

Each channel of the AIM9 carrier amp module is provided with phase and quadrature (R and C) balance potentiometers, as well as individual potentiometers for gain from ×1 to ×20. Each channel also has its own excitation drive controlled from a master oscillator. The oscillator frequency can be switch selected from 1kHz to 20kHz in five steps. The selectable frequency optimizes the dynamic frequency response of the transducers and minimizes offset errors associated with the phase shift differences between signal and excitation.

The AIM9 can be used in conjunction with either the Series 500 or System 570 mainframes. When used with the Series 500, a selection of either 12-bit (1 part in 4096) or 14-bit (1 part in 16,384) is available. Up to nine AIM9 modules can be installed into the Series 500, providing up to 18 channels of transducer input. When used with the System 570, the AIM9 adds two channels of transducer input with 12-bit A-D resolution.





INPUT CHARACTERISTICS

Input Channels (Local): 2, differential and balanced to ground.

Gain: Adjustable per channel, 1 to 20.

Input Dynamic Range: 3.5V peak max without distortion.

Input Protection: ±15V max (powered)
±10V max (unpowered)

Input Impedance: 100kΩ in parallel with 47pF, each input.

Common Mode Rejection: >90dB at 60Hz.

Nonlinearity: 0.05% of full scale.

Quadrature Balance Range: Adjustable, ±90°.

Phase Balance Range: Adjustable, ±125mV @ ×1 gain.

Bandwidth: Software selectable five pole filter (−3dB), 2, 20, or 200Hz, maximally flat, −30dB/octave.

Settling Time (to 0.1%): 2Hz: 1000ms
20Hz: 100ms
200Hz: 20ms

Noise: Residual carrier with 10:1 or greater oscillator to filter ratio), 1mV p-p.

Temperature Coefficient: Gain: 200ppm/°C. Offset: 100ppm/°C.

EXCITATION CHARACTERISTICS

Frequency: Selectable per system, 1kHz, 2kHz, 5kHz, 10kHz, or 20kHz with master/slave synchronization for up to 10 modules.

Frequency Accuracy: ±3%.

Amplitude: 5V rms ±10%.

Third Harmonic Distortion: 1%.

Amplitude Stability vs. Load (100Ω min.): <0.01%.

Temperature Coefficient: Frequency: ±200ppm/°C. Amplitude: 40ppm/°C.

LVDT or variable inductance transducers sense changes in position, as opposed to strain gages which sense changes in force. While LVDTs lend themselves to applications of large changes in position and displacement (angular displacement for RVDTs), variable inductance transducers are especially suited to applications of small displacements, such as differential pressure measurements.

The LVDT is made up of three coils wound on a common form with a movable core of magnetic material (**Figure 1**). Ac excitation is applied to the center or primary coil, and through magnetic flux in the armature, induces voltage in the two outside or secondary coils. When the core is displaced from center, induced voltage is increased in one secondary coil and decreased in the other. This difference in voltage can be measured and related to the position of the movable core. Connection of the secondary coils in series opposing allows linear measurement of the core above and below the null or center position.

In the case of the variable inductance transducer (**Figure 2**), the minute changes in the metal diaphragm position between the two coils causes the magnetic reluctance to vary with the gap. The overall effect of the diaphragm motion is a change in the inductance ratios of the two coils and is best detected using a bridge circuit.

FIGURE 1: Typical Linear Variable Differential Transformer Transducer

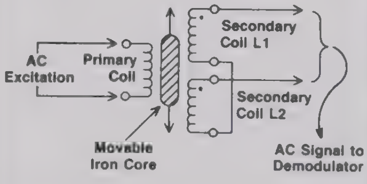
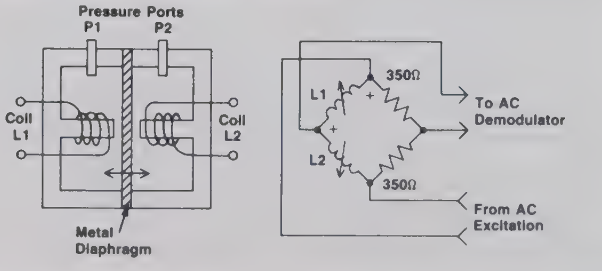


FIGURE 2: Typical Variable Inductance Transducer



Analog Output Modules/**AOM1, AOM2**

12-Bit, 16-Bit

The **Analog Output Module 1 (AOM1)** offers true 12-bit resolution with a maximum nonlinearity of ±0.012%. The AOM1 is available in two versions: the AOM1/2 provides 2 channels of analog output, and the AOM1/5 provides 5. Each channel has an independent D/A converter with switch-selected output ranges of 0 to +10V and 0 to +5V unipolar, and ±10V, ±5V, and ±2.5V bipolar. Signal connection is made through on-card screw terminals.

The module's strobe feature is supported by two levels of data latching in the D/A converter and allows synchronous updating of all analog output channels.

The AOM1 may be placed in any slot of the Series 500 baseboard.

OUTPUT CHARACTERISTICS

Output Channels (Local): AOM1/2: Two. AOM1/5: Five.

Output Ranges (switch selectable for each channel): ±2.5V, ±5V, ±10V, 0 to +5V, 0 to +10V.

Resolution: 12 bits.

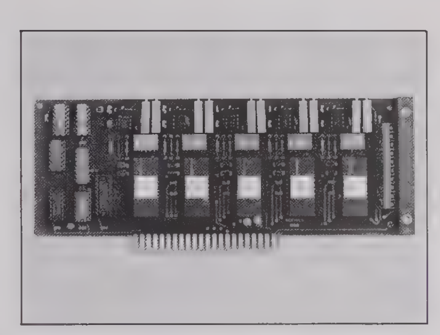
Nonlinearity: ±0.012% of full scale (±½ lsb) max.

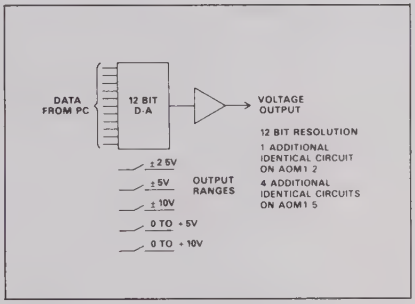
Output Impedance: 0.1Ω.

Load Characteristics: 5kΩ min., 1000pF max., short circuit protected.

Slew Rate: 5μs to 0.01% of full scale transition.

Temperature Coefficients (±% of full scale/°C): Gain: 0.0016%, unipolar ranges; 0.0023%, bipolar ranges. Offset: 0.006%, unipolar ranges; 0.0010%, bipolar ranges.




DATA
FROM PC
12 BIT
D·A
VOLTAGE
OUTPUT
12 BIT RESOLUTION
1 ADDITIONAL
IDENTICAL CIRCUIT
ON AOM1 2
4 ADDITIONAL
IDENTICAL CIRCUITS
ON AOM1 5
±2 5V
±5V
±10V
OUTPUT
RANGES
0 TO +5V
0 TO +10V

The **High Resolution Analog Output Module 2 (AOM2)** offers true 16-bit resolution D/A conversion with maximum non-linearity of ±0.0015%. The AOM2 is available in two versions: the AOM2/1 provides one channel of output, and the AOM2/2 provides 2. Each channel has an independent D/A converter and a range selection switch. Signal connection is made through on-card screw terminals.

The range selection switches can be set for two output ranges: ±10V and 0 to +10V. Optional filter capacitors help preserve the converter's 16-bit accuracy through the reduction of noise. The module's strobe feature is supported by two levels of data latching in the D/A converter and allows synchronous updating of all analog output channels.

The AOM2 may be placed in any slot of the Series 500 baseboard.

OUTPUT CHARACTERISTICS

Output Channels (Local): AOM2/1: One. AOM2/2: Two.

Output Ranges (switch selectable for each channel): ±10V, 0 to +10V.

Resolution: 16 bits.

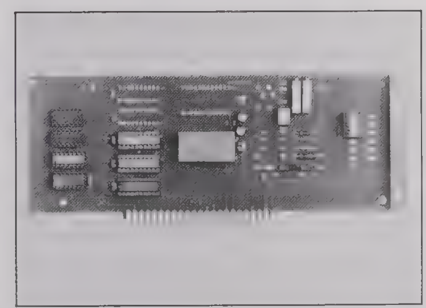
Nonlinearity: ±0.0015% of full scale.

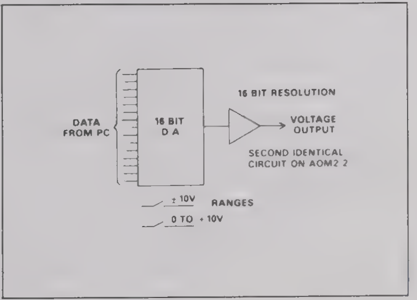
Output Impedance: 0.1Ω.

Load Characteristics: 2kΩ min., 1000pF max., short circuit protected.

Slew Rate: 20μs to 0.006% of full scale transition.

Temperature Coefficients (±% of full scale/°C): Gain: 0.0007%, 0 to +10V range; 0.0009%, ±10V range. Offset: 0.0009%, 0 to +10V range; 0.0011%, ±10V range.




DATA
FROM PC
16 BIT
D A
16 BIT RESOLUTION
VOLTAGE
OUTPUT
SECOND IDENTICAL
CIRCUIT ON AOM2 2
±10V
RANGES
0 TO +10V

AOM3, AOM4/Analog Output Modules

Current Output, Programmable Excitation

The **Current Output Module 3 (AOM3)** provides four channels of 0-20mA current output through four independent D/A converters. The D/A converters offer true 12-bit resolution with maximum non-linearity of ±0.012%. Each channel has a single output range of 0-20mA and resolution of 5μA. Each current output can be supplied by either the internal +15V supply or an external supply of up to +26V dc.

The module's strobe feature is supported by two levels of data latching in the D/A converter and allows synchronous updating of all analog output channels.

The AOM3 may be placed in any slot of the Series 500 baseboard.

OUTPUT CHARACTERISTICS

Output Channels (Local): 4.

Output Range: 0 to +20mA, source only.

Resolution: 12 bits; 1 lsb = 5μA.

Nonlinearity: ±0.012% of full scale (±½ lsb).

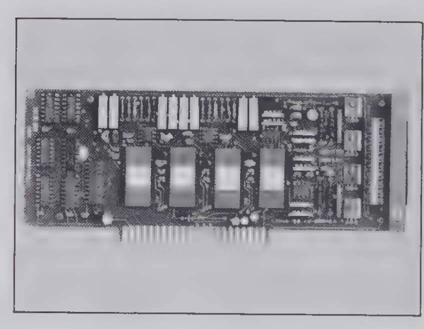
Output Impedance: ≥2.5MΩ at dc.

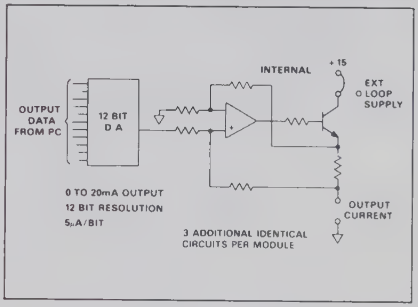
Loop Supply: Internal: +15V. External: +10V to +26V (user supplied).

Load Characteristics: No minimum load requirements.

Settling Time: 1ms to 0.01% of final output.

Temperature Coefficients: Gain: 0.0075% of reading/°C. Offset: 0.0005mA/°C.




OUTPUT DATA FROM PC
12 BIT D A
INTERNAL
+ 15
EXT LOOP SUPPLY
0 TO 20mA OUTPUT
12 BIT RESOLUTION
5μA/BIT
OUTPUT CURRENT
3 ADDITIONAL IDENTICAL CIRCUITS PER MODULE

The **Programmable Excitation Source (AOM4)** is an analog output module featuring four channels of independent voltage output with a current source capacity of up to 40mA. The AOM4 is ideal for the excitation of strain gages, load cells, and other sensors requiring excitation, and may also be used where outputs must be maintained at higher current levels. Signals are connected directly to the module via on-card screw terminals.

Each D/A converter offers true 12-bit resolution with maximum non-linearity of ±0.012%. The voltage output level is software-selected across a fixed range of 0 to +10V, with resolution of 2.5mV and maximum output current of 40mA. Each voltage output can be supplied by either the internal +15V supply or an external supply of +15 (+2, −0) V dc.

The module's strobe feature is supported by two levels of data latching in the D/A converter and allows synchronous updating of all analog output channels.

The AOM4 may be placed in any slot of the Series 500 baseboard.

OUTPUT CHARACTERISTICS

Output Channels (Local): 4.

Output Range: 0 to +10V (source only).

Resolution: 12 bits, 1 lsb + 2.5mV.

Nonlinearity: ±0.012% of full scale (±½ lsb).

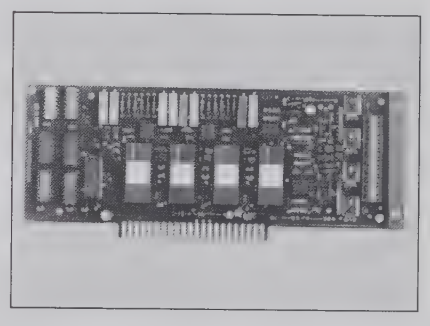
Output Impedance: 0.1Ω.

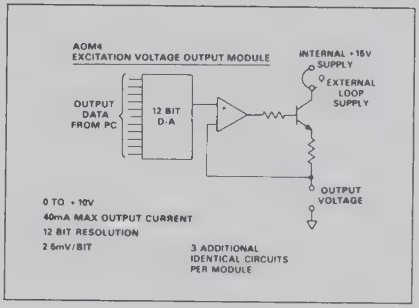
Load Characteristics: 256Ω min., 0.1μF max., short circuit protected.

Settling Time: 500μs to 0.01% of final output.

External Supply (user provided): 15V min., 17V max.

Temperature Coefficients: Gain: 0.0016% of reading/°C. Offset: 0.1mV/°C.




AOM4
EXCITATION VOLTAGE OUTPUT MODULE
INTERNAL +15V SUPPLY
EXTERNAL LOOP SUPPLY
OUTPUT DATA FROM PC
12 BIT D-A
OUTPUT VOLTAGE
0 TO +10V
40mA MAX OUTPUT CURRENT
12 BIT RESOLUTION
2.5mV/BIT
3 ADDITIONAL IDENTICAL CIRCUITS PER MODULE

Digital Input/Output Modules/**DIO1, DIM1**

32 Channel I/O, 16 Channel Input

The **Digital Input/Output Module 1 (DIO1)** provides 32 programmable digital input and output channels at TTL levels. The channels are grouped into four 8-bit ports with each port individually selected for input or output by on-card DIP switches. Digital inputs have a rapid settling time, and asynchronous reading of output data is made possible with latched outputs.

I/O connections are accomplished through quick disconnect screw terminal blocks provided with the module. Connections are made to on-card screw terminals that accept 16-24 AWG wire leads, or to the on-card 40-pin connector which accepts a mass terminated ribbon cable.

The DIO1 module can be installed in any available slot in the Series 500 baseboard.

Channels: 32, switch-selectable in groups of 8 for input or output.

Signal Connection: Quick disconnect screw terminal blocks plus 40-pin receptacle for ribbon cable assembly.

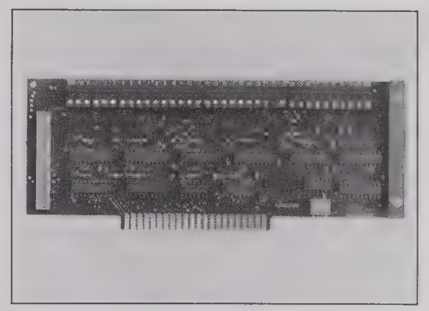
Input Characteristics: TTL-compatible, high true high-level input current, 20μA; low-level input current, -0.4mA.

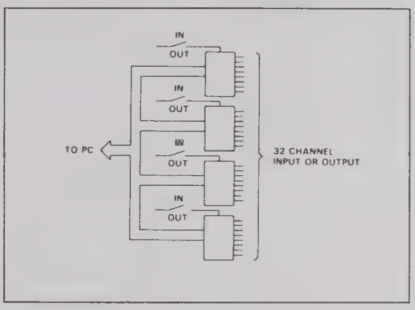
Output Characteristics: TTL-compatible, high true drive capability 10 TTL loads, 24mA sink at 0.5V.

Accessories: 6 ft. ribbon cable assembly, 40-conductor, one end mates with 40-pin receptacle on DIO1, other end unterminated.

NOTE: All inputs and outputs referenced to system ground. If isolated inputs/outputs are required, see DIM1 and DOM1.

DIO1 modules do not contain a power-on reset, and output at power-up is random. For applications requiring a known state at power-up, use a DOM1, PCM1, or PCM2.





The **Digital Input Module 1 (DIM1)** provides 16 channels of optically isolated digital input with resistor programmable thresholds from +5V to +28V. Each channel is optically isolated from system circuitry and other input channels. The settling time of the isolation circuit is 5μs, allowing sampling of high-speed digital inputs. As shipped, the module is configured for 16 TTL inputs.

Digital input channels can be accessed either as 16 individual lines or in two ports of eight channels each; each port is treated as a single byte in Soft500 software.

The DIM1 module may be placed in any slot of the Series 500 baseboard.

INPUT CHANNELS

Local: 16.

INPUT CHARACTERISTICS:

TTL-Compatible, Low True Logic 1 Drive: 14mA sink at <0.5V.

ISOLATION:

Technique: Optical.

Channel-to-Ground: 500V peak max.

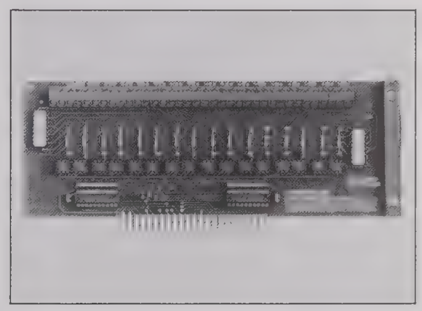
Channel-to-Channel: 0 (jumper plugs installed).

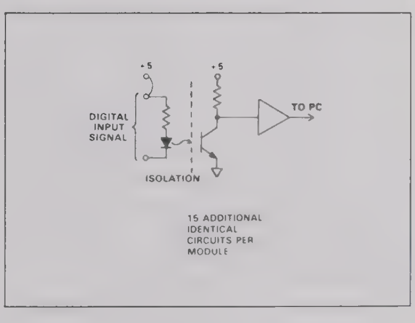
USER-CONFIGURABLE CHARACTERISTICS:

Input Voltage: Up to +28V max.

Channel-to-Channel Isolation: 500V peak (jumper plugs removed).

External Supply Requirements (for channel-to-channel isolation): 5V to 28V @ 14mA/channel.





DOM1, PCM1/Digital Output, Power Control Modules

16-Channel Digital Output; AC Output

The **Digital Output Module 1 (DOM1)** provides 16 channels of optically isolated digital output. These channels are factory-configured as TTL-compatible voltage outputs, optically isolated from each other and from system circuitry. User-configurable components on the module enable each channel to be configured for TTL-compatible or up to +28V output voltage or current output, and isolated or non-isolated operation.

Digital output channels can be accessed either as 16 individual lines or as two ports of eight channels each; each port is treated as a single byte in Soft500 software. This grouping allows simultaneous updating of up to eight channels, and enables communication with 4- and 8-bit TTL devices.

The DOM1 includes a power-on reset circuit to ensure a known condition at startup. It may be placed in any slot of the Series 500 baseboard.

OUTPUT CHANNELS

Local: 16.

OUTPUT CHARACTERISTICS

TTL-Compatible Logic 0 Output: 0.4V max. @ 1.6mA sink.

Logic 1 Output: 3.75V min. @ 1mA source.

Transition Time: 100µs.

ISOLATION:

Technique: Optical.

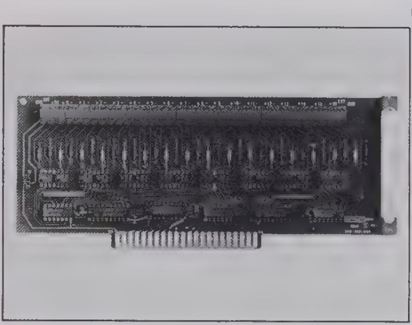
Channel-to-Ground: 500V peak max.

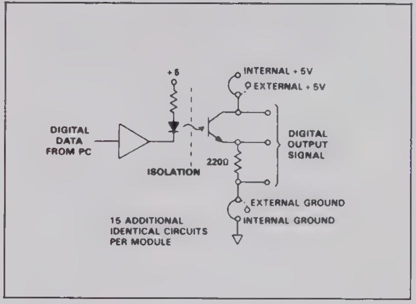
Channel-to-Channel: 500V peak max.

USER-CONFIGURABLE CHARACTERISTICS:

Output Voltage: 28V max. (user-supplied source).

Output Current: 50mA max. (user-supplied source).





The **Power Control Module 1 (PCM1)** is designed to switch on and off ac line devices—motors, lamps, and solenoids—without disturbing the operation of the computer or the Series 500.

The PCM1 provides 4 channels of switching for ac power signals of 12 to 140V at up to 3A. Each channel is switched through an independent solid state relay, with full optical isolation to 1000V ac and short-circuit protection. The PCM1 includes a power-on reset circuit to ensure a known condition at start-up. It is used specifically to control devices operating on ac line voltages.

The PCM1 consists of two elements: the PCM1 card, which plugs into the Series 500 baseboard, and a remote signal connection unit, at which all ac connection and switching takes place. This keeps potentially dangerous and noisy ac voltage outside of the system case. An 8-foot ribbon cable links the remote unit to the plug-in module. The PCM1 may be placed in any available slot in the Series 500 baseboard.

The PCM1 module includes four OAC-120 solid-state relays (see PCM2 specifications for details on OAC-120).

OUTPUT CHANNELS: 4.

OUTPUT CHARACTERISTICS:

Configuration: Ac output.

Operating Voltage: 12-140V ac.

Frequency: 25-65Hz.

Current: 3A max. @ 25°C; derate to 1A @ 70°C. 20mA min., 50A peak for 1 cycle surge.

Voltage Drop: 1.6V max. (device on).

Leakage: 5mA max. (device off).

Power Factor: Up to 0.5.

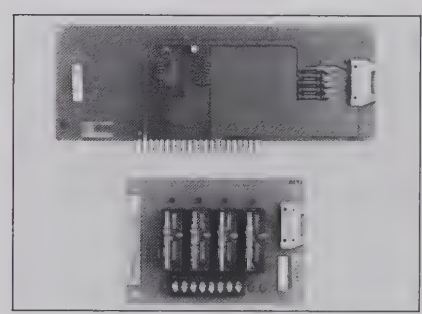
Switch Form: 1 pole normally open.

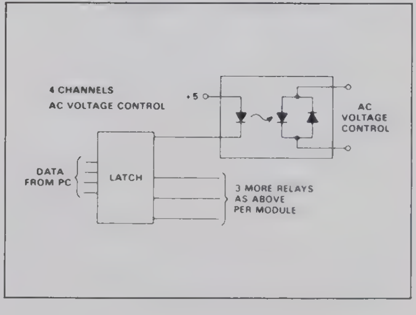
Switching Technique: Optically isolated solid-state switch.

Operating Temperature: −30 to 70°C.

Isolation: 1000V rms input to output; 350V rms channel-to-channel.

Status Indication: LED for each channel "on", screw terminals for #16-24 AWG wire, 8 ft. ribbon cable to mainframe card (TTL signals).





Power Control Modules/**PCM2, PCM3**

AC/DC Control & Sensing

The **AC/DC Power Control and Sensing Module 2 (PCM2)** is a general purpose control subsystem for the sensing and control of power ac and dc devices. Ideal for demanding control applications in scientific and industrial automation systems, the PCM2 permits the direct interface of relays, heaters, motors, actuators, and a wide variety of ac and dc devices, over the full range of voltages from 10V to 280V. The PCM2 includes a power-on reset circuit to ensure a known condition at start-up. The system is fully opto-isolated and protected from overloading. All connections are made to high-current screw terminals. Since the relays are industry standard, plug-in, solid-state elements, the system is readily configurable as the application requires.

The PCM2 provides up to 16 channels of power interface. Each channel can be configured with plug-in relays to dc input, dc output, ac input, or ac output. Each channel is short-circuit protected with plug-in fuses, and isolated to 1000V ac. Control channels can switch up to 3A. LED indicators are provided on the remote unit to indicate channel status.

The PCM2 consists of two elements: the PCM2 interface card, which plugs into the Series 500 baseboard, and a remote unit which keeps potentially hazardous and noisy signals outside the system environment. The remote assembly can be mounted in a variety of positions, and the PCM2 may be placed in any available slot in the baseboard.

The **AC/DC Power Control Relay Mounting Board (PCM3)** is the remote unit described above. The PCM3 is for use with the System 570 in power control applications.

NOTE: The System 570 does not support IAC or IDC power sensing input relays.

CONTROL CHANNELS

Input or Output: Up to 16. PCM2 requires specific input and/or output modules.

OUTPUT CHARACTERISTICS:

Configuration: Any combination of plug-in modules (ac, dc, input, output).

Operating Temperature: −30 to +70°C.

Status Indication: LED for channel "on".

Isolation: 1000V rms input to output; 350V rms channel-to-channel.

Connections: Screw terminals for #14-24 AWG wire, 4 ft. ribbon cable to mainframe card (TTL signals).

MODULES FOR PCM2:

AC OUTPUT:	**OAC-120**	**OAC-240**
Operating Voltage:	12-140V ac	24-280V ac

Frequency: 25-65Hz.

Current: 3A max. @ 25°C; derate to 1A at 70°C. 20mA min., 50A peak for 1 cycle surge.

Voltage Drop: 1.6V max. (device on).

Leakage: 5mA max. (device off).

Power Factor: Up to 0.5.

Switch Form: 1 pole normally open.

Technique: Optically isolated solid-state switch.

Switching Time: ½ cycle max. (10ms @ 50Hz).

DC OUTPUT:	**ODC-60**	**ODC-200**
Operating Voltage:	10-60V	10-200V
Current: At 25°C:	3A	1A
At 70°C:	1A	0.3A

Voltage Drop: 1.6V max. (device on).

Leakage: 2mA max. (device off).

Switch Form: 1 pole normally open.

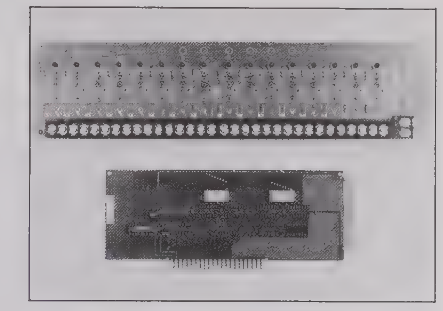
Technique: Optically isolated solid-state switch.

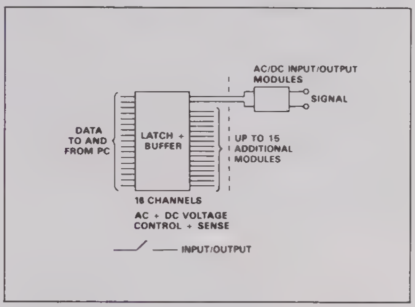
Switching Time: 1ms max.

AC INPUT:	**IAC-120**	**IAC-240**
On State Input:	90-140V	180-280V
Input Current:	12mA max.	7mA max.
Off Voltage:	<25V ac (2mA)	<50V ac (1mA)

Technique: Optically isolated solid-state switch.

Switching Time: 20ms max.




AC/DC INPUT/OUTPUT MODULES
SIGNAL
DATA TO AND FROM PC
LATCH + BUFFER
UP TO 15 ADDITIONAL MODULES
16 CHANNELS
AC + DC VOLTAGE CONTROL + SENSE
INPUT/OUTPUT

DC INPUT:	**IDC-32**
Dc Input:	10-32V.

On State Input: 25mA max. @ 32V.

Off Voltage: <1V (1mA).

Reverse Voltage: 32V max.

Technique: Optically isolated solid-state switch.

Switching Time: 5ms max.

PIM1, PIM2/Pulse Counting Modules

8-Channel Frequency Input, 4-Channel Event Counting

The **Pulse Input Module 1 (PIM1)** provides 8 multiplexed frequency inputs. Eight software-controlled ranges allow frequency measurements up to a maximum of 8MHz and down to a resolution of 1Hz. The PIM1 offers 16-bit hardware resolution, plus a 16-bit cascadable software counter, for a combined count of over 4 billion. Seven of the input channels on the PIM1 provide selectable isolated (to 400V) or non-isolated TTL-compatible inputs, while the eighth channel has a non-isolated sensitivity of 200mV.

As a frequency counter, the seven TTL-compatible inputs provide measurements to 8MHz in the non-isolated mode, and to 2MHz in the isolated mode. The low-level channel measures up to 1MHz, non-isolated only.

Input channel, input gating, gate times, and frequency/event modes are selected from software. Gate times between 1048.6ms and 8.2ms allow a wide range of frequencies to be measured.

The PIM1 module may be placed in any slot of the Series 500 baseboard.

Input Channels (Local): 8.

Channel 0 Non-Isolated Sensitivity: 200mV min. @ 1MHz.

Maximum Input: 50V dc or peak ac.

Minimum Rise and Fall Time: 5V/second.

Input Impedance: 100kΩ/1000pF.

CHANNELS 1-7 (non-isolated)

Logic 0 Drive: 1.4mA sink at <1V.

Logic 1 Drive: 0mA source at >1.4V (internal pull up to +5V).

CHANNELS 1-7 (isolated)

Logic 0 Drive: 10mA forward current.

Logic 1 drive: <250μA forward current.

ISOLATION

Technique: Optical (switch-selectable on channels 1-7).

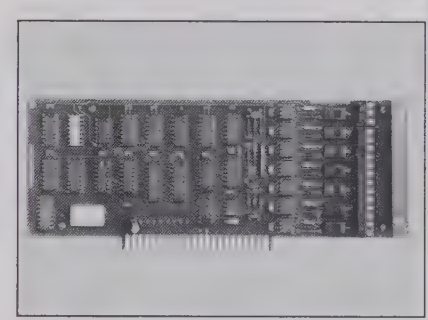
Channel-to-Ground: 500V peak max.

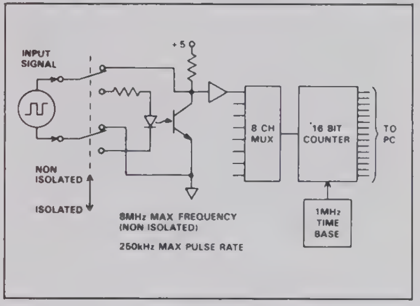
Channel-to-Channel: 500V peak max.

FREQUENCY MODE

RANGE*	GATE TIME (ms)	RESOLUTION (Hz)	ACCURACY ±(% + Hz)
8 MHz	8.19	122	0.04 + 122
4 MHz	16.38	61	0.04 + 61
2 MHz	32.77	30	0.03 + 30
1 MHz	65.56	15	0.03 + 15
500 kHz	131.07	7.5	0.03 + 7.5
250 kHz	262.14	3.7	0.03 + 3.7
125 kHz	524.29	1.9	0.03 + 1.9
62.5 kHz	1048.58	1	0.03 + 1

*In isolated mode, maximum input is 2MHz. Channel 0 maximum input is 1MHz.





PULSE COUNTING MODE (Single Channel):

Input Pulse Rate: 250kHz max., with anti-coincidence.

Pulse Width: 2μs min.

Maximum Count: With hardware counter only: 65,535. With cascadable software counter: 4,294,967,296.

The **Pulse Input Module 2 (PIM2)** provides four channels of simultaneous event counting or totalizing operations. Each of the four channels can count up to 65,536 events, or the first channel may be cascaded to the second for events totaling over 4 billion counts. TTL-compatible input pulses can be totalized at rates up to 250kHz. Each channel has provisions for external gate control of its 16-bit counter. This allows custom applications of period measurements using external TTL-compatible oscillators. Other Series 500 modules like the DOM1 Digital Output Module can be connected to the gate or direct inputs of the PIM2 for programmed timing applications. The PIM2 is ideal for multichannel event counting/totalizing measurements, while the PIM1 is ideal for multichannel frequency measurements. All of the inputs to the PIM2 are non-isolated. For applications requiring isolated inputs, consider the PIM1 module, but keep in mind that the PIM1 is not capable of multichannel simultaneous event counting.

INPUT CHARACTERISTICS

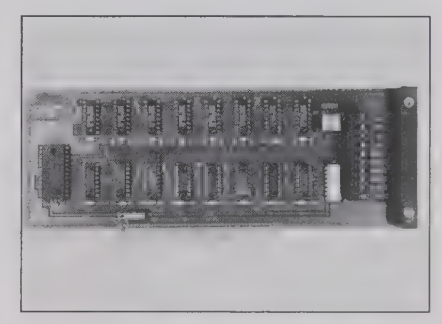
Input Channels: 4, LS TTL compatible, Schmitt trigger.

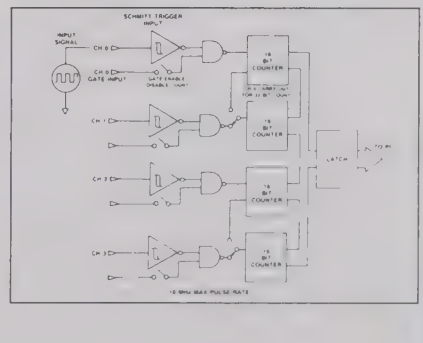
Signal Duration: 2μs minimum.

Maximum Count: 65,635 (16 bits) on each of four channels; 4,294,967,295 (32 bits) when two channels are cascaded.

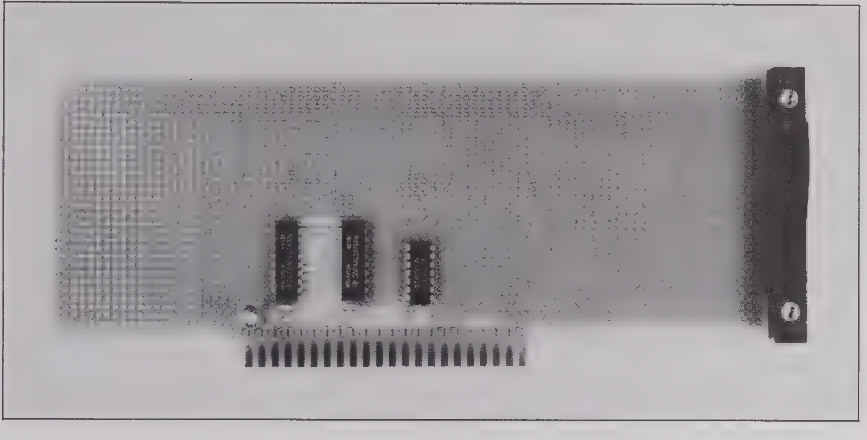
Gate Input Channels: 1 per input, LS TTL compatible, high true with internal pull-up resistor provided.

Input High: 3.2V minimum.
Input Low: 0.4mA @ 0.9V maximum.
Signal Duration: 2μs minimum.



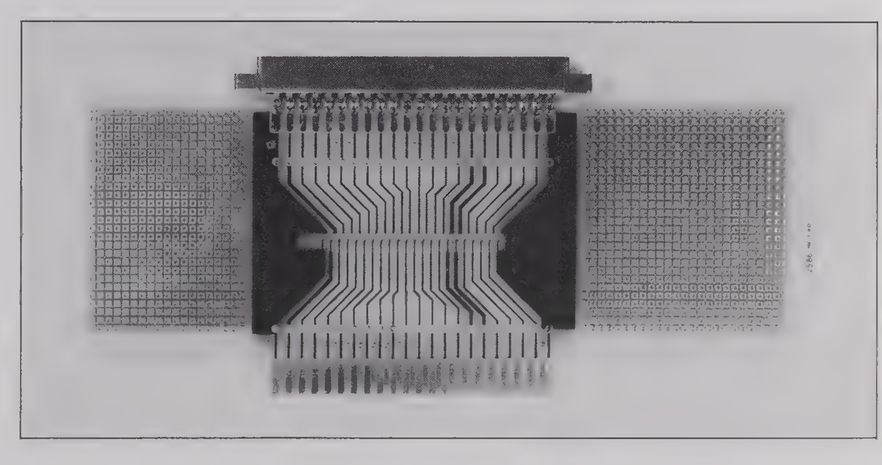


The **Prototyping Module (PROTO)** enables users to design and interface their custom circuits to the Series 500 or System 570. All Series 500 slot signals are available on the PROTO module, including supply voltages and grounds. The PROTO module includes interface logic for one TTL-compatible 8-bit bidirectional data port. This allows 8-bit data transfers to and from the user-designed circuitry on the PROTO module. One byte of data can be written to or read from the module using the slot dependent CMDA address. Software control of the registers on the module can be accessed through BASIC's PEEK and POKE commands or through Soft500. Soft500 uses the PROTO module as if it were a PCM2 for configuration and data transfer purposes.



The **EXTEND Module** extender board is ideal during the setup or calibration of the various modules in the Series 500 mainframe. For example, the strain gage module can be used with the extender card, thus allowing connections to be made and jumpers changed during initial setup. Adjustments of offset and excitation level can also be tested prior to final installation.

In addition, the EXTEND module has provisions for minor circuit development on either side of the bus extension lines. Together, the PROTO and EXTEND modules are valuable design and calibration aids for the Series 500 mainframe.

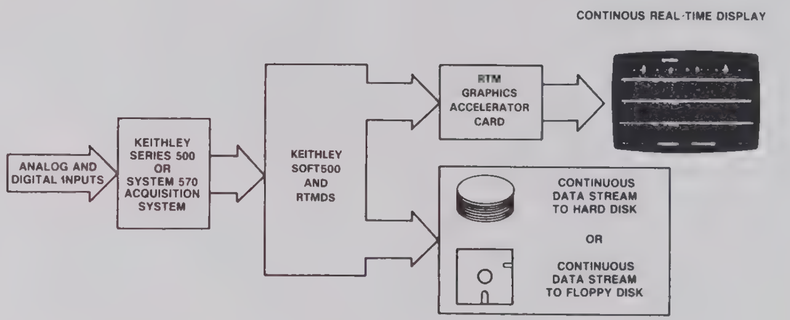


RTMDS/Real Time Monitor & Direct Storage System

Multichannel Waveform Monitor Interface with Direct Storage Software

The RTMDS system enhances Soft500's graphics functionality with greater speed and improved appearance. The system works in two modes: as simple enhancements to Soft500, or as RTMDS. As enhancements to Soft500, it takes the place of the real time graphics commands in Soft500. The commands look the same, but their speed is increased by an order of magnitude. As RTMDS it can be run in a non-programming mode, allowing interactive high speed acquisition and direct-to-disk storage that can be run either stand-alone or from within Soft500 (**Figure 1**).

FIGURE 1: Functional Block Diagram


CONTINOUS REAL-TIME DISPLAY
ANALOG AND DIGITAL INPUTS
KEITHLEY SERIES 500 OR SYSTEM 570 ACQUISITION SYSTEM
KEITHLEY SOFT500 AND RTMDS
RTM GRAPHICS ACCELERATOR CARD
CONTINUOUS DATA STREAM TO HARD DISK
OR
CONTINUOUS DATA STREAM TO FLOPPY DISK

SOFT500

- **Real time data plotting directly on the computer's monitor through unique graphics accelerator card**
- **Does not interfere with computer generated video information**
- **Real time or post acquisition operation so data may be plotted while being acquired, or after acquisition from memory or disk**

Soft500, Keithley's measurement and control software, has allowed multichannel waveform monitoring for many applications emulating stripchart recorders or data loggers. But, when applications required emulation of oscillographic recorders or oscilloscope operations, the PC becomes overburdened. Now, with the addition of the RTM graphics accelerator card, this burden is taken away from the PC so it can perform more important tasks such as engineering units conversions and data storage. By allowing investigators to monitor their signals in a traditional way with the ability to interact with the display (similar to changing sweep speeds on an oscilloscope without having to stop the display program) brings to PC based data acquisition unprecedented enhancement to laboratory automation. Researchers will no longer have to acquire data completely blind of the changes occurring in their experiments or depend on expensive analog instrumentation to provide the "quick look" of signal status.

RTMDS

- **Continuous data streaming to floppy or hard disk at rates up to 5000 samples per second (PC-AT)**
- **Two selectable real time data display modes: continuous smooth scroll (chart recorder-like) and triggered sweep (oscilloscope-like) allow bright, clear plotting of both low and high frequency waveforms**
- **Supports up to 16 channels of direct storage with simultaneous display of up to any 8 channels**
- **Ten different display format selections including multiple display windows and overlapping and nonoverlapping traces for maximum display flexibility**

Dataq Instruments' Computer-based Oscillograph and Data Acquisition System is a combination hardware/ software package that allows continuous data throughput to floppy or hard disk while maintaining a real time waveform display on the host computer's monitor. When integrated with the Keithley Series 500 or System 570 PC-based data acquisition systems, it becomes RTMDS and fulfills the original expectation of personal computers as laboratory chart recorders: multichannel real time monitoring of signal waveforms before, during, and after acquisition of data. The RTM graphics accelerator card occupies one long expansion slot within the PC, and is connected between the CRT monitor and the existing graphics adapter. The RTM board is supported by the IBM family of personal computers with the noncomposite IBM compatible monochrome, color, or enhanced graphics monitors.

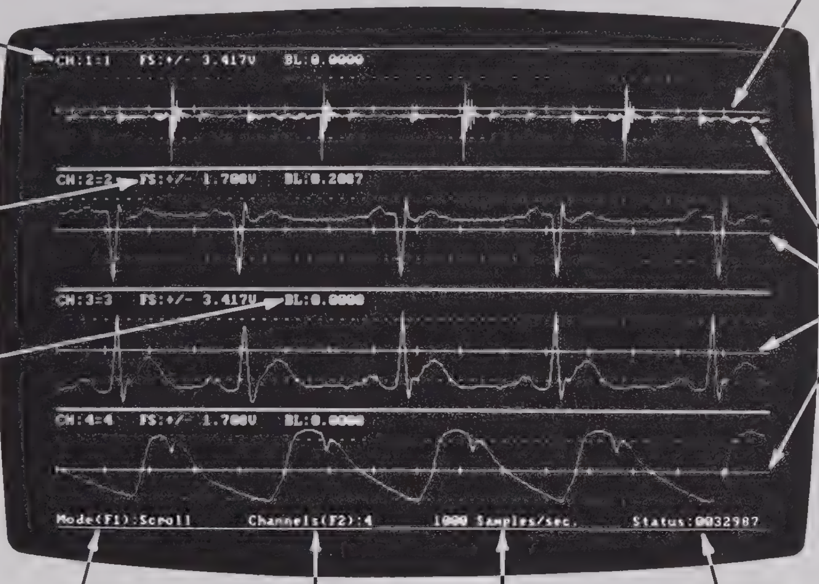
The RTM card provides programmable continuous, bi-directional smooth scroll (horizontal pan) or triggered sweep display modes with a fixed vector plot time of only 64μs for IBM personal computers (**Figure 2**).

When in the scroll mode of operation, digitized data are represented as a smooth scrolling graph in chart recorder-like fashion with absolutely no flashing or jerking. In the triggered sweep mode of operation, trigger level, slope, and source definitions are used to provide triggered sweep waveform plotting. Built-in trigger condition testing ensures that a periodic waveform will appear the same from one screen sweep to the next.

Unprecedented speed and flexibility describe the RTMDS approach to waveform plotting. By moving the plot task out of the software and into the hardware domain, the RTMDS dramatically enhances the overall performance of Keithley computer-based data acquisition systems.

Multichannel Waveform Monitor Interface with Direct Storage Software

FIGURE 2: Typical Four-Channel Screen


CH:1=1 FS:+/- 3.417V BL:0.0000
CH:2=2 FS:+/- 1.700V BL:0.2087
CH:3=3 FS:+/- 3.417V BL:0.0000
CH:4=4 FS:+/- 1.700V BL:0.0000
Mode(F1):Scroll
Channels(F2):4
1000 Samples/sec.
Status:0032987

Input channel number assigned to a specific display window. Typing "1 = 4" would assign channel 4 to display window 1.

Gradicule marker used when making time per division measurements.

Selected ± full scale voltage for the display window.

Four typical real time waveforms.

Base line voltage (changed from a default value of 0 by introducing offsets to a specific display channel). May be used to view signals having large offsets.

Graphics accelerator card's display mode: Scroll or Oscilloscope.

Number of input channels enabled for acquisition.

Selection sample rate (when F5 is pressed, will display time per division).

Number of samples stored to disk (continuously increments during acquisition).

WAVEFORM PIXEL RESOLUTION: Selectable 640×350, 640×200, 400×350, 400×200 pixels.

WAVEFORM DISPLAY MODES: Selectable continuous smooth scroll, or triggered sweep.

NUMBER OF WAVEFORM DISPLAY FORMATS: Ten.

NUMBER OF WAVEFORM DISPLAY CHANNELS: Eight.

NUMBER OF STORAGE CHANNELS: Sixteen.

MAXIMUM REAL TIME DISPLAY THROUGHPUT RATE: 2000Hz (PC-XT) or 5000Hz (PC-AT).

MAXIMUM CONTINUOUS THROUGHPUT TO DISK ACQUISITION RATE: 2000Hz (PC-XT) or 5000Hz (PC-AT).

SAMPLE RATE RANGES (STEP): 5-10 (1), 10-100 (10), 100-1000 (100), 1000-5000 (1000) sample per second.

PLOT FORMAT: Continuous dot-joining.

TRIGGERED SWEEP CONDITIONS:

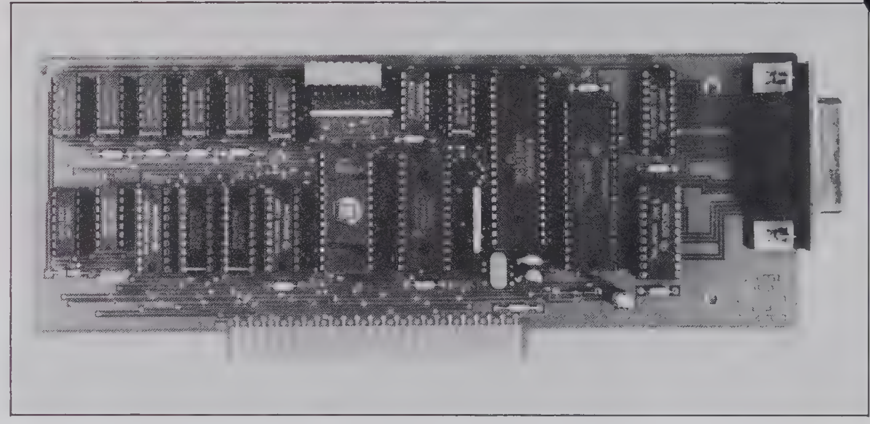
Trigger Modes:	Selectable Auto/Normal.
Trigger Level (Normal Mode):	+32767 to −32768.
Trigger Source:	Any displayed channel.
Trigger Slope:	Positive/negative.

OVERLAPPING WAVEFORM COLOR/INTENSITY:

Monochrome:	Even channels bright, odd channels dim.
Color:	8-color selectable.

EXPANSION SLOT REQUIREMENTS: One long expansion slot.

GPIB/IEEE-488 Controller Module



The **IEEE-488 Controller Module (GPIB)** installs into slot 10 of the Series 500 (or the expansion slot of the System 570) and adds IEEE-488 instrument control to either system. With the GPIB module, up to 14 IEEE-488 instruments can be interfaced to the system, taking advantage of the same Soft500 environment as the Series 500 or System 570. Unlike other PC-installable IEEE-488 boards, the GPIB has integrated IEEE-488 control into **single-line** commands, which results in programs that are easy to write as well as easy to read.

The GPIB module has an on-board microprocessor, which converts high-level IEEE-488 commands from Soft500 into the IEEE-488 bus protocol and handshaking. The commands provide simple English-like instructions for bus activities. The command set provides a complete offering of IEEE-488 capabilities, including:

- Input and output of strings, numeric data, or arrays
- Software programmable terminators, guaranteeing compatibility with all IEEE-488 instruments
- Complete serial and parallel poll implementation
- Low-level control of the bus, for applications requiring specific bus transactions

COMMAND SUMMARY

Command	Description
ABORT	Assert INTERFACE CLEAR. Assert ATN and send MY TALK ADDRESS.
CLEAR	Send DEVICE CLEAR to all devices.
CLEAR16,12	Send SELECTED DEVICE CLEAR to 16 and 12.
ENTER	Read GPIB input buffer.
ENTER14	Read data from device 14.
ENTER14;CR	Same as ENTER14 except terminate on carriage return.
ENTER14;8000	Same as ENTER14 except terminate after 8000 bytes have been transferred.
ENTER1403	Same as ENTER14 except send secondary address 03.
ENTER20'data';CR	Same as OUTPUT20;data and ENTER20;CR.
HELLO	Power-on verification. Response is ''500-IEEE488 Rev x.x'.
LOCAL	Return all devices to local control.
LOCAL09	Return device 09 to local control.
LOCALLOCKOUT	LOCAL LOCKOUT all devices.
OUTPUT;data	Send data to the active listener.
OUTPUT12;data	Send data to device 12.
OUTPUT1215;data	Same as OUTPUT12 except send secondary address of 15.
OUTPUT12*128;data	Same as OUTPUT12 except send 128 bytes of data plus terminator(s).
PPOLL	Conduct a PARALLEL POLL.
PPOLLCONFIG28;03	Configure device 28 with PARALLEL POLL response in DIO3 and assert it low true
PPOLLUNCONFIG	Send PARALLEL POLL UNCONFIGURE.
PPOLLDISABLE03	Disable device 03 from a PARALLEL POLL response.
REMOTE	Assert REMOTE ENABLE line.
REMOTE03,25	Assert REMOTE ENABLE and address devices 03 and 25 to listen.
RESET	Warm start the GPIB.
RESUME	Unassert the ATTENTION line.
SEND;commands	Send individual bus commands UNT, UNL, MTA, LISTENaddr, TALKaddr, ENTER, DATA'xxxx', DATAn,m,...q, CMD'xxxx', or CMDn,m,...q.
SPOLL	Get SERIAL POLL status from GPIB.
SPOLL15	SERIAL POLL device 15.
TERM;CR EOI	Set IEEE-488 bus terminator.
TRIGGER04,18,22	TRIGGER devices 04, 18, and 22.

The GPIB module simplifies the task of integrating Series 500 hardware with IEEE-488 instruments. There are two ways to use this capability: In the first application, the Series 500 is central to the measurement. Most of the measurement I/O is through the 500, but there are a few special measurements. You might need a Keithley Model 485 for picoampere measurements, or a Keithley Model 194 for high-speed acquisition. By having the GPIB in the Series 500, you don't have to monopolize a slot in your PC to support these few special measurements.

In the second application, most of your system is IEEE-488 based. For this application we recommend a System 570 with the GPIB plugged into the expansion slot. You get IEEE-488 control, and the System 570 takes care of many of the miscellaneous requirements in your system such as bus extension, digital I/O ports, power control to turn on other equipment in the experiment, analog control outputs, and high speed 12-bit A/D conversion. In this application the System 570/GPIB combination functions as a multiprogrammer.

A simplified integration of the Series 500 with IEEE-488 instruments is shown at the right, compared to our previous Plus500 approach. The new program is shorter and easier to understand and debug.

IEEE-488-1978 INTERFACE

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, PP0, RL0, DC1, C0, E1.

CONTROLLER SUBSETS: C1, C2, C3, C4, and C10 of IEEE-488-1978.

TERMINATOR: Switch selectable CR, LF, CR-LF, LF-CR, and/or EOI.

CONNECTOR: Standard Amphenol 57-20240 with metric studs.

SAMPLE PROGRAM

1. Send Interface Clear to initialize the bus.
2. Place a digital multimeter (Model 195A) in the REMOTE mode.
3. Clear the multimeter of all programmable states.
4. Program the multimeter for a range and function (R3T3X).
5. Serial poll the multimeter.
6. Display the serial poll byte.
7. Trigger the multimeter to take a reading.
8. Input a reading from the multimeter.
9. Display the reading.

Plus500

```
10 CLEAR,50000!
20 IBINIT1 = 50000!
30 IBINIT2 = IBINIT1 + 3
40 BLOAD "BIB.M",IBINT1
50 CALL IBINIT1(IBFIND,IBTRG,
   IBCLR,IBPCT,IBSIC,IBLOC,
   IBPPC,IBBNA,IBONL,IBRSC,
   IBSRE,IBSRY,IBPAD,IBSAD,
   IBIST,IBDMA,IBEOS,IBTMO,
   IBEOT)
60 CALL IBINIT2(IBGTS,IBCAC,
   IBWAIT,IBPOKE,IBWRT,IBWRTA,
   IBCMD,IBCMDA,IBRD,IBRAD,
   IBSTOP,IBRPP,IBRSP,IBDIAG,
   IBXTRC,IBSTA%,IBERR%,
   IBCNT%)
70 A$="GPIB0"
80 CALL IBFIND(A$,BRD0%)
90 A$="DEV16"
100 CALL IBFIND(A$,M195%)
110 Y%=16
120 CALL IBPAD(M195%,Y%)
130 CALL IBSIC(BRD0%)
140 IF IBSTA%<0 THEN STOP
150 Y%=1
160 CALL IBSRE(BRD0%,Y%)
170 IF IBSTA%<0 THEN STOP
180 CALL IBCLR(M195%)
190 IF IBSTA%<0 THEN STOP
200 CMD$="R3T3X"
210 CALL IBWRT(M195%,CMD$)
220 IF IBSTA%<0 THEN STOP
230 CALL IBSRP(M195%,A%)
240 IF IBSTA%<0 THEN STOP
250 PRINT A%
260 CALL IBTRG(M195%)
270 IF IBSTA%<0 THEN STOP
280 RD$=SPACE$(25)
290 CALL IBRD(M195%,A$)
300 IF IBSTA%<0 THEN STOP
310 PRINT A$
```

IEEE-488 Controller

```
10 OPEN"\DEV\IEEEOUT" FOR
   OUTPUT AS 1
20 OPEN"\DEV\IEEEINP" FOR INPUT
   AS 2
30 PRINT#1,"ABORT"
40 PRINT#1,"REMOTE 16"
50 PRINT#1,"CLEAR 16"
60 PRINT#1,"OUTPUT 16;R3T3X"
70 PRINT#1,"SPOLL 16"
80 INPUT#2,A
90 PRINT A
100 PRINT#1,"TRIGGER 16"
110 PRINT#1,"ENTER 16"
120 INPUT#2,A$
130 PRINT A $
```

STEP1, STEP2/Stepper Motor Control Modules

STEP1: μP Stepper Motor Controller
STEP2: Stepper Motor Indexer

- **Continuous speed control from 1sps to 65,535sps**
- **Up to 4 motors controlled with one STEP1 and four STEP2s**
- **Microprocessor logic—no adjustments required**
- **Absolute and relative positioning modes**
- **Step and direction outputs**
- **14 high level commands**
- **4 independent internal motor-specific command buffers for sequential execution of up to 66 commands each**
- **15 programmable linear acceleration and deceleration rates**
- **Continuous speed adjustment without stopping motor**
- **Programmable maximum positioning speed of up to 16,000sps**
- **Readable status register for each motor; indicates direction, positioning mode, limit condition, and motion complete indicator**
- **Abort capability; stops selected motor immediately, resets limit-condition, purges selected motor's unexecuted commands**
- **Unlimited number of steps in continuous speed operation**

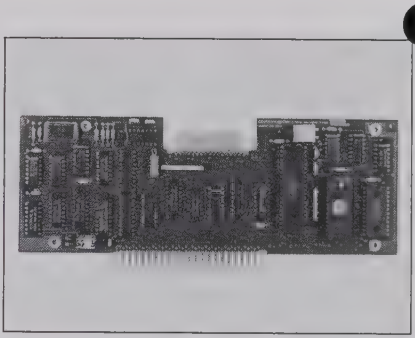
The Series 500 Stepper Motor Control Modules are a multi-module set for the control of up to four stepper motor axes. The STEP1 module is a microprocessor based command module which controls from one to four STEP2 modules. Each STEP2 module functions as an indexer for position and speed control of one stepper motor through a stepper motor power driver.

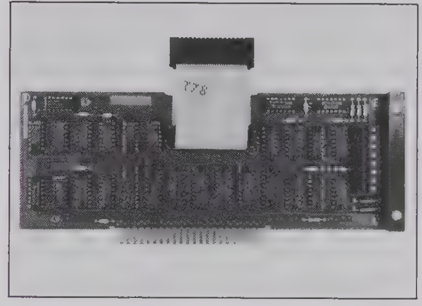
All Series 500 communication to the stepper motor modules is through the STEP1 module using a high-level command set. All axes in the system operate independently of one another. Motors in the system can be in different operating modes, different directions, and different maximum positioning speeds. The only exception is ramp rate, where all four axes require the same acceleration and deceleration rates.

Incoming commands that have not yet been executed are buffered. This enables multiple commands to be sent to the STEP1 module to be executed sequentially. All functions of the stepper motor control modules are software programmable.

The STEP1 module receives high level commands from the PC via the Series 500 interface. Operating as an intelligent peripheral, the on-board microprocessor of the STEP1 module interprets these commands and generates the necessary pulse stream to control motor velocity, acceleration, position, and direction through the individual STEP2 Indexer Modules. This allows the user of the Series 500 to approach automated motion control as a peripheral function.

Unique to the Keithley Series 500 is that data acquisition and motion control can be controlled from the same system, allowing for complete solutions to laboratory automation applications.





Stepper Motors
Motor drivers or translators are available from most stepper motor manufacturers. Most drivers accept digital step and direction inputs from the STEP2 Indexer Module. Internal to the driver are drive logic and power amplifiers to set and maintain output current levels for the motor. Drivers are available that provide not only full step logic but also half step or even microstep logic for demanding, high resolution motor applications.

Based on the speed, torque, and resolution required, numerous stepper motors are available from various manufacturers. Motors are available with step angles from 15° per step to 0.72° per step. This is equivalent to from 24 to 500 steps per revolution. Through the translator/driver, resolution of 500spr can be extended to 1000 spr in the half step mode or even to as much as 32,000 in the microstep mode, where each pole of a 500 step motor is further divided into as many as 64 finer steps. This high resolution provides digitally controlled motion that is effectively continuous, even at low velocities. Microstepping can provide the positioning accuracy of an analog servo system and retain the simple, digital nature of a step motor.

Excellent applications information and assistance is available from many of these manufacturers for both selecting and applying stepper motors and drivers. The following is a partial listing of these companies:

Berger-Lahr Corp., Fitzgerald Dr., Jaffrey, NH 03452, (603) 532-7701
Bodine Electric Co., 2500 W. Bradley Pl., Chicago, Ill. 60618, (312) 478-3515
Eastern Air Devices, 1 Progress Dr., Dover, NH 03820, (603) 742-3330
Sigma Instruments, 170 Pearl St., Braintree, MA 02184, (617) 843-5000
The Superior Electric Company, 383 Middle St., Bristol, CT 06010, (203) 582-9561

Motion Control
There are three basic parts to an incremental motion control system: the indexer, the driver, and the motor. The indexer receives the high level commands, such as position, from a computer. It then interprets these commands and generates the proper control signals for the driver, a specialized power amplifier. The driver provides the correct voltages and currents for the motor, which provides mechanical rotation to move the load.

A typical single-axis system consists of a stepper motor, a drive, an indexer, and a controller or microprocessor. The drive moves the motor one step for each pulse received from the indexer. The STEP2 Indexer Module receives commands from the STEP1 microprocessor module and generates the appropriate pulse stream.

Speed Control
The STEP1 and STEP2 modules form an incremental motion control system. Each pulse sent to the driver causes the motor to move one step, half step, or microstep. A string of pulses of a given frequency will cause the motor to rotate at a velocity proportional to that frequency. This is not subject to drift since there are no analog velocity feedback devices required to regulate the motor's speed.

Typical speed control applications include conveyors, precision pumps, and crystal growing machinery.

Position Control
The amount of motor rotation is equal to the number of pulses applied to stepper motors. The speed and positioning of the motor can be controlled digitally by an indexer. Pulse positioned systems are inherently more noise-immune than analog servos. This is important in many applications where the PC, STEP1 and STEP2 indexer, and the driver are in different locations or are subject to excessive electrical noise.

Position control applications are numerous, and include milling machine table positioning, robotics, camera controls, and valve positioning.

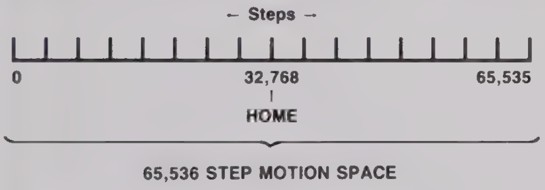
Acceleration Control
To prevent stalling or to achieve slew speed when stepping a motor, acceleration control is also needed. A typical motion profile is trapezoidal, ramping up smoothly from rest to some preset velocity, and then decelerating smoothly to a stop. The acceleration/deceleration rate and the preset velocity depend on the nature of the load being moved and the overall move time.

A special case of the trapezoidal move profile occurs when the preset distance is too short or the acceleration rate is too slow to reach the preset velocity. In this case, the move profile becomes triangular. In a triangular move profile, one half of the move is spent accelerating and the other half is spent decelerating.

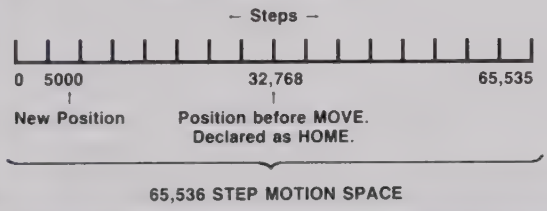
The STEP1 automatically selects the move profile based on the commanded acceleration, velocity, and distance.

Incremental motion control devices are used in a wide variety of applications because of their simplicity, precision, and durability. In many cases, the performance of the machine or apparatus utilizing step motors has been significantly enhanced.

ABSOLUTE POSITION OPERATION



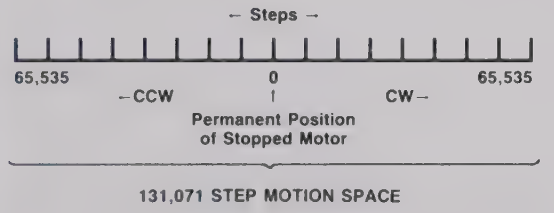
EXAMPLE: Set absolute position mode for Motor A.
Set present position to HOME.
Move to position 5000.



In absolute positioning mode, the stepper motor control module must be told what step in the 65,536-step motion space it should assign to the selected motor's present location. The SET PRESENT POSITION TO HOME command will assign the present position of the motor to 32,768, the center of the 16-bit motion space. The SET PRESENT POSITION TO A VALUE command will assign the present position of the selected motor to the value of the parameter accompanying the command byte. After this assignment is made, the MOVE TO POSITION command will consider its accompanying parameter to be the absolute location that the motor should go to. If the parameter is higher than the present position, the motor will go in a CW direction to attain its new location. If the parameter is lower, the motor will go CCW to attain its new location. The motor will always remember where it is presently and seek the position commanded.

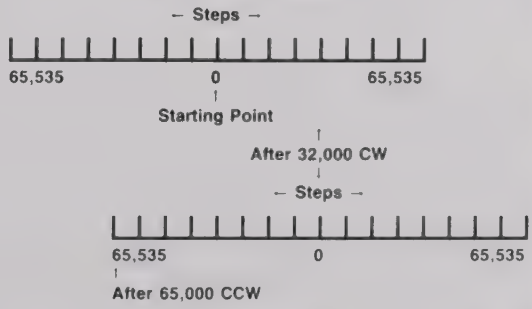
RESULT: Motor A moved 27,768 steps in a counter-clockwise direction. If motor A was now commanded to RETURN HOME, it would move 27,768 steps in a clockwise direction.

RELATIVE POSITIONING MODE



In relative positioning mode, the stepper motor control module always assumes that all moves are relative to its present position. The parameter that accompanies the MOVE TO POSITION command is now considered to be the number of steps that should be moved from the present motor position in the direction set by the direction commands.

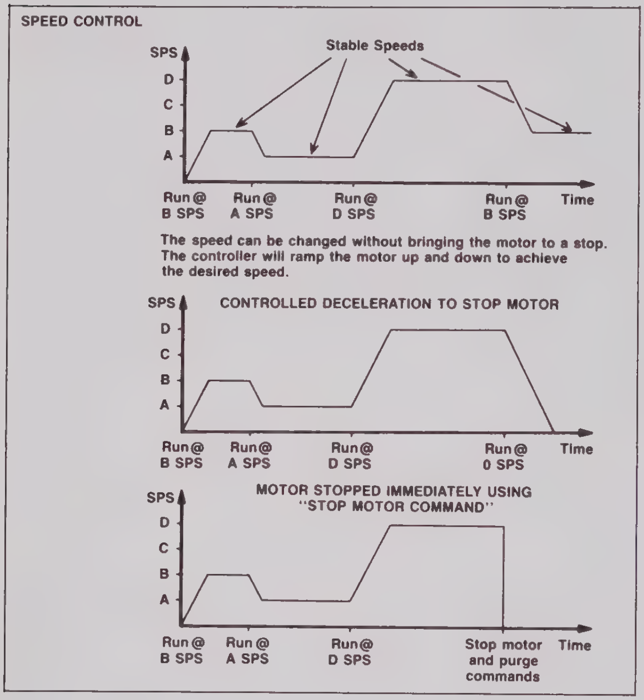
EXAMPLE: Set relative position mode for Motor A.
Set CW direction.
Move to position 32,000.
Set CCW direction.
Move to position 65,000.



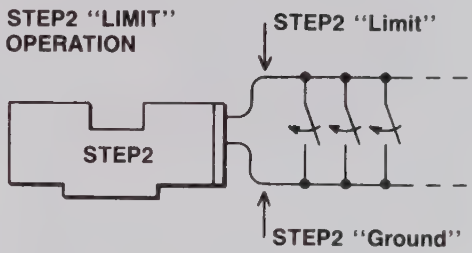
RESULT: Motor A moves 32,000 steps CW, then stops and moves 65,000 steps CCW. Final position is 33,000 steps CCW from its original position.

STEP1, STEP2/Stepper Motor Control Modules

STEP1: µP Stepper Motor Controller
STEP2: Stepper Motor Indexer



The speed can be changed without bringing the motor to a stop. The controller will ramp the motor up and down to achieve the desired speed.


STEP2 "LIMIT" OPERATION
STEP2 "Limit"
STEP2
STEP2 "Ground"

A switch closure at the LIMIT input of a STEP2 module will stop the motor that is controlled by that STEP2 module. The limit condition will be reflected in the status byte for the motor.

The direction bit in the status byte will indicate in which direction the motor was turning when the limit occurred, and will differentiate between multiple limit switches if more than one switch was used. This information will enable the user application program to make a decision as to its action after a limit has been reached.

Configuration: One STEP1 required to drive 1 to 4 STEP2 modules.

Channels: One motor channel per STEP2 module.

STEP2 Outputs: LS TTL compatible, high true.
Output High: 0.4mA source @ 2.7V min.
Output Low: 4mA sink @ 0.4V max.
Output Signals: Four: cw/$\overline{\text{ccw}}$, ccw/$\overline{\text{cw}}$, pulse, $\overline{\text{pulse}}$.

STEP2 Limit Input: LS TTL compatible, low true or switch closure to ground (internal pull-up resistor provided).
Input High: 3.2V min.
Input Low: 0.4mA @ 0.9V max.
Signal Duration: ≥50ns.

Slew Rate: 1 to 65,535 steps per second maximum in 1sps increments, software programmable.

Speed Accuracy: 0.01% of full scale frequency.

Positioning Modes: Absolute: 65,536 positions.
Relative: ±65,535 steps.

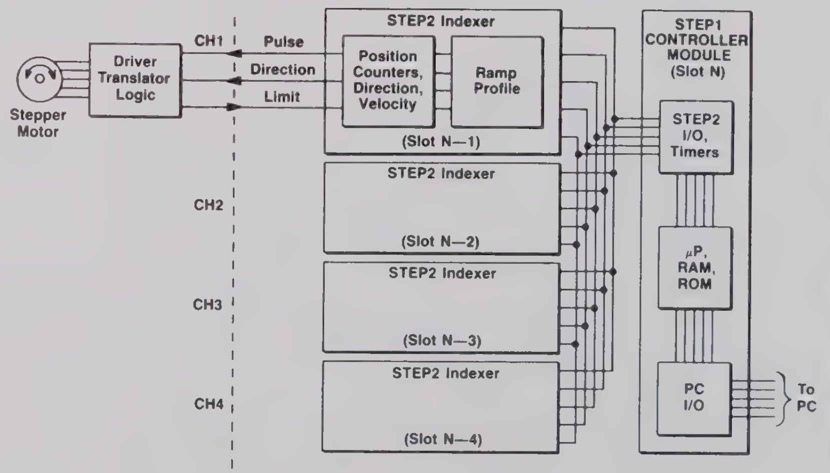
Positioning Speed: 16,000sps maximum, software programmable.

Ramp Rates: 15 rates, software selectable from 4,096sps^2 to 32,768sps^2.

STEP1 On-Board Microprocessor: 6809 8/16 bit.

Command Buffer Size: Approx. 66 commands per motor.

Commands: 14 high level commands callable from BASIC and fully integrated with Keithley's Soft500 extended BASIC measurement and control software.


Stepper Motor
Driver Translator Logic
CH1
Pulse
Direction
Limit
CH2
CH3
CH4
STEP2 Indexer
Position Counters, Direction, Velocity
Ramp Profile
(Slot N—1)
STEP2 Indexer
(Slot N—2)
STEP2 Indexer
(Slot N—3)
STEP2 Indexer
(Slot N—4)
STEP1 CONTROLLER MODULE (Slot N)
STEP2 I/O, Timers
µP, RAM, ROM
PC I/O
To PC

Introduction

The variety and complexity of data acquisition and analysis software available for personal computers make selecting the proper software for a particular application difficult. Factors that make these decisions difficult are basic to software in general, but once understood can be used in selecting data acquisition software. There are three major factors: ease of use, adaptability, and processing speed. For each of these factors there is a spectrum along which particular application packages can be classified (**Figure 1**).

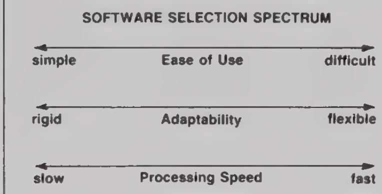
Software Selection Spectrum

Ease of Use. On one end of the spectrum are the "simple" systems that are intuitive; using them requires minimum study. Systems that fall into this category are based on state-of-the-art user interfaces and are highly interactive (i.e. menus and windows). They also have many safety features built in, and it is usually difficult to get these systems to crash.

On the other end of the spectrum are the "difficult" systems based on a programming language, the most difficult one being assembly language coding for a particular processor. In this case you must design, implement, and debug your system from nothing at all. At best, you are provided with a set of good software tools that streamline the programming task.

Adaptability. "Rigid" systems are designed to do one thing very well (e.g. a system designed to do data acquisition but which relies on other programs to process the data). These systems generally have a predefined model from which they cannot deviate. They are limited in their ability to make decisions and to adapt themselves to different applications. These systems, again, are based on state-of-the-art user interfaces. A menu, for example, does not allow any choices except those provided by the menu. If you want something else you must wait for the system to be modified by the developers. "Flexible" systems are based on some type of programming language, which allows the user to make decisions on what the program will do under various conditions. The system will do exactly what the user wants. It can also be changed to allow for changing requirements.

FIGURE 1.



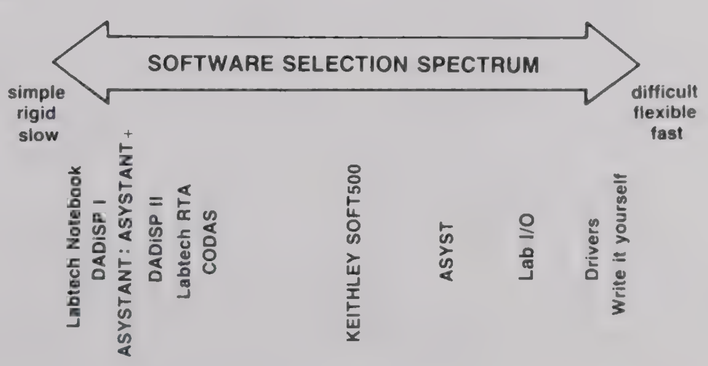
Processing Speed. This is a system's overall performance in real time use. For data acquisition systems this can mean several things: first, how fast the system can acquire and store data; second, how fast the system can analyze the data; third, how fast the system can display the data—can it do real time graphics or only post-acquisition display of data; and fourth, can this system perform control functions—can it make decisions in real time and how powerful is the decision making capability. "Slow" systems allow data to be acquired at relatively low data rates (up to about 100Hz). They typically cannot do control or any real time decision making. Generally, the more "foolproof" a system is, the slower it runs. If the system must constantly check for incoming data going out of range, for instance, it cannot concentrate its full time and attention to data acquisition, and therefore runs slower. A "fast" custom software package written to satisfy particular applications can outperform any "canned" software package. A custom software package eliminates many generalizations in the implementation that slow the system down. It also takes advantage of the full power of a particular hardware configuration.

These three factors—ease of use, adaptability, and processing speed—define a single spectrum with the easy, rigid, slow systems on one end and the difficult, flexible, fast systems on the other. The easier to use a system is, the more rigid it becomes and the slower it operates. This is due to the large amount of error checking that must be done to handle the large diversity of applications to which the system may be applied. On the opposite end of the spectrum are the systems which are programming environments. The user is free to leave out any error checking that is not required in his application; he can customize the system to his particular hardware; and he can also implement any control algorithms that he chooses. **Figure 2** shows this single spectrum and the placement along the spectrum of some commercially available software packages. The placement of these systems on the diagram is based on their generally accepted strong points.

Software Packages and Programming Environments

Drivers and **write it yourself** on the diagram in **Figure 2** provide a frame of reference. (Since the user is writing everything, he is going to get just what he wants as long as he has sufficient skills to complete the program.) The drivers help this situation somewhat by

FIGURE 2.



eliminating the task of writing the actual hardware interface software, which is the most difficult task.

LAB I/O: A package of C drivers and utilities for the Series 500. The package works with popular C compilers such as Lattice and Microsoft. This can make short work of some programming tasks, but it is still programming and requires good programming skills.

Labtech Notebook is a completely menu driven environment. Its strong points are ease of use and the ability to transfer data to other high-powered analysis packages. Its weaknesses are in speed and analysis capabilities, although it does include FFT analysis, thermocouple conversion, and PID loop control.

Labtech RTA is a system that provides real time access to the Labtech drivers from other software packages. It is limited in speed, but provides an easy way of doing data acquisition in real time without programming.

ASYST is a programming environment that combines some of the elements of a "tool box" approach into an interpretive programming language similar to Forth. It is a flexibile and powerful system for those that don't mind programming. Its strong points are fast data acquisition, support for many hardware products, and extensive analysis and graphics capabilities specifically designed for scientific applications.

ASYSTANT and ASYSTANT+ are actually an additional layer of software that isolates the user from the programming of ASYST. They are menu-driven analysis and acquisition packages.

DADiSP I and **DADiSP II** are, respectively, an acquisition and an analysis package. Module I is intended for the Keithley Series 500 and System 570 hardware. It is a completely window/menu-driven product that makes the task of acquiring data very simple. It is very easy to use and can move data easily to other analysis packages. It is somewhat slow, however, and can do only simple triggering for acquisition and offers no control.

RTMDS, an enhanced version of CODAS, is used to simulate a strip chart recorder, and it does this very well. It supports our RTM's graphics accelerator card. It is easy to use and extremely fast, with the additional advantage that it can stream data to disk for later recall. It is, however, limited to applications that can be served by a strip chart.

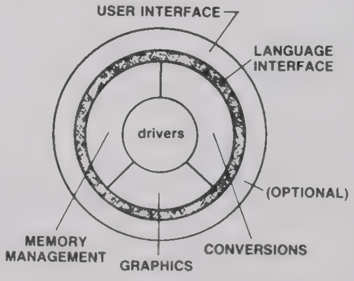
Soft500 is designed to fully support the Series 500 and System 570. It is an extension of the GWBASIC programming environment that provides a powerful set of data acquisition routines along with additional routines for graphics and data conversions. Its strong point is that it is easy to use, since you work within interpretive BASIC, and it does data acquisition at relatively high rates. Its weak point is its speed limitation for user algorithms written in BASIC. This product is an intermediate step between the ends of the spectrum, and it combines some of the best elements of both.

Quick500 is a compilable extension to GWBASIC that uses the MS Quick BASIC compiler. Its command structure is the same as that of Soft500.

Software Model

Another approach to analyzing software products is to understand the basic building blocks upon which all of the existing software products are based. Most products contain a user interface level, a language interface level, a filter level that has data handling and analysis capabilities, and a driver level that actually runs the particular hardware. The power and scope of these levels determine the usefulness of the software. Knowledge of these levels provides insight into the factors that affect overall system performance and compatibility with different hardware products (**Figure 3**).

FIGURE 3.



This method views the levels as concentric layers. At the core are the hardware interface routines, or drivers. These routines manipulate the hardware to read or write data. In some packages these routines also provide timing for the data acquisition. The implementation of these routines has a profound impact on the overall speed and performance of the system. Software suppliers write their own drivers for a host of different hardware products. The problem with supporting many different hardware devices is that you usually cannot take full advantage of the capabilities of all of the products. The best source of drivers for a piece of hardware is usually the supplier of that hardware. Most hardware manufacturers supply drivers; however, they supply nothing else.

The next layer of software above the drivers is the filter layer. These routines format the raw data. In this layer are conversions, memory management, and graphics. Conversions are used to change the data from raw binary to various other units of measure. Examples are volts, milliamps, degrees Celsius, and PSI. Many of these operations are simply linear conversions, but as in the case of thermocouples, the conversion may be non-linear. Handling these conversions at this level provides increased performance compared to doing them in a high-level language (e.g. BASIC).

Memory management functions provide a way to use the available memory in the computer for storage of large data arrays. In many systems data arrays are limited to 64K, while in others they can be as large as the available storage in the machine. This is very important when large amounts of data must be acquired very quickly. One solution to memory limitations is the option of stream buffers of data to disk. This feature is only now becoming a standard in many software packages.

The graphics layer allows display of the results of data acquisition on a CRT. These routines provide features such as data versus time plots as well as multidimensional plots of information. These capabilities, combined with numeric conversions, allow very quick analysis of data. One feature that is difficult to find in many of the software packages is real time display of data. In most systems, this feature is limited to relatively slow data acquisition rates (10's of Hz). Recently, some hardware assists, such as the RTMDS card, have become available that allow real time acquisition and display in the kHz range.

The next layer above the filtering layer is the interface layer. These routines constitute what the applications programmer sees when programming the system in a particular language. Whether it be ''C'', or PASCAL, or BASIC, these routines are the only entry point into the system. The advantage of having a distinct layer to handle this function is that the lower layers of software can be written in the developer's language of choice, but the system can be accessed from the user's language of choice. Supporting different user languages requires only that the developers supply a different interface layer for each language. The bulk of the software, however, can remain the same.

Advanced user interfaces are becoming more common, and with them an additional layer of software called the user interface layer. This software provides a complete environment within which the user must work. The most sophisticated ones provide windows and menus for viewing and processing data in numeric and graphic forms. The idea behind these interfaces is to provide a high degree of functionality and at the same time prevent the user from getting into trouble. The menu choices should be self-explanatory, and help is provided in case of confusion. The whole system should operate in a consistent fashion. The main drawback to these types of programs is that they are limited and somewhat slow. They can do only what the designer intended them to do. If the user needs a particular feature and it does not appear on any of the menu selections, he is simply out of luck. The additional levels of error checking required by these systems tend to limit their speed.

In this software model, the progressions from the core of drivers to the user interface at the outer layer explains the software selection spectrum. Each layer makes the system easier to program and more functional, but it also restricts the system's versatility and slows down its execution speed.

Choosing Software

To choose a software package, determine where your application lies along the software selection spectrum. Then decide if your programming skills match or exceed the skills needed for your application. If they do, consider the following: 1. Cost of the software; 2. Time you will spend programming and troubleshooting your application; and 3. Future application needs. Often a simple package that gets you started quickly runs out of steam as the application becomes more complex. Since different packages excel in different aspects of data acquisition, you could easily find that you need several packages.

Finally, a word of caution. If your programming skills do not match your application, turn the job over to someone who has the requisite skills. Most of these software packages are good learning tools and can help you develop your skills, but they are not turn-key packages.

Soft500/Software System

Version 5.0

Soft500 is an extension to BASIC created to utilize the capabilities of the Keithley Series 500 Measurement and Control Workstations and the IBM series of personal computers. Soft500's foreground and background architecture, as well as its integration with the capabilities of Microsoft BASIC, provides a powerful measurement and control environment. Merging Soft500 with Microsoft GW-BASIC extends the compatibility of the Series 500 to include many similar 100% IBM-compatible computers such as Compaq, Honeywell, NCR, Sperry, Leading Edge, and Zenith. This listing of compatibility has been verified by Keithley. In addition, modifications have been made to Soft500 so that the advantages of higher μP clock speeds of 6 and 8MHz can be incorporated.

Programming Series 500 workstations with the new modules is accomplished via Soft500 Version 5.0 Soft500 runs under IBM PC Advanced BASIC (BASICA) included in IBM PC-DOS (versions 3.1, and 3.2 are recommended). Compaq computers must run Soft500 Version 5.0 under Compaq DOS 3.0 or later, with the matching BASICA version. Soft500 Version 5.0 also runs on most 100% IBM-compatible computers which use Microsoft MS-DOS and the respective version of Microsoft GW-BASIC.

Soft500 allows three modes of measurement and control: singleground, foreground, and foreground/background.

Singleground Operation. Singleground operation is ideal for high speed single channel acquisition to 31kHz, or even for multichannel high speed acquisition with aggregate speeds of 7 channels/ms on 6MHz AT's. The number of channels that can be acquired in 1ms, for example, will depend on whether the PC is an XT or AT, or if the μP is running at 4, 6, or 8MHz.

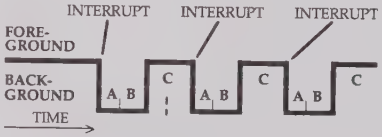
Foreground Operation. The foreground mode of data acquisition is the easiest to implement, and is ideal for non-time-critical modes of operation with limited amounts of data. The amount of memory available for data arrays is only 64K, because the commands are directly under BASIC's control when data acquisition takes place in the foreground. The foreground mode of operation is perfectly adequate if all that is required is to take a few measurements of signals that are not dynamic. A good application would be for a preamble program of calibrations and scaling routines prior to precisely timed acquisition of a dynamic signal.

FIGURE 1: How Soft500 Executes in the Foreground/Background Architecture

Sample Soft500 Program

`110 CALL ANIN`	Multiple channel scan of specified input channels to execute once every interrupt. Task A.
`120 CALL ANOUT`	Analog output of array of data to execute once every interrupt on specified channel. Task B.
`130 CALL INTON`	Start interrupts at specified rate up to 1kHz.
`140 CLS:SCREEN 1`	BASIC commands prepare screen for graph.
`150 CALL GRAPHRT`	Real time graphing of input in foreground. Task C. Foreground can be used for any sequence of BASIC or non-time-critical SOFT500 commands.

Real time graphics takes place in foreground while data acquisition and control goes on in background.



Foreground/Background Operation. The foreground/background mode of data acquisition is fully managed by Soft500 using the precision timing of the interrupts. All commands that take place in the time-critical background have been precisely timed to execute within exact time periods. These commands include analog and digital input sampling, analog or digital triggering, output sampling, mathematical commands, and memory management of data. This is ideal for data acquisition as well as control applications (**Figure 1**).

Soft500 has complete command of all background data acquisition and control tasks, while BASICA has control of all foreground tasks. In addition to BASICA, Soft500 Version 5.0 has the ability to run concurrently with programs such as LOTUS and WORDSTAR in the foreground concurrent with Soft-500 background acquisition.

Precise Data Sampling

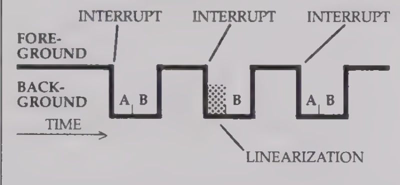
A unique aspect of Soft500 and its foreground/background architecture is how it carefully controls the timing of data sampling. Attempting to manage a large number of concurrent tasks will often result in data skewing as low-priority tasks cause execution of sampling and output to be delayed. Sampling at the wrong time is a source of error independent of accurate instrumentation and cannot be easily incorporated into an error term. The degree of error is equal to the difference between the measured signal and its value at the scheduled sampling time. Soft500 has features to control timing:

Hardware Interrupts. Soft500 uses the precision timers on the interface board to generate the interrupts that drive time-critical tasks. The more common timing solution of software delays and counters does not allow for the precise control that hardware timers provide. Interrupts in Soft 500 are accurate to 1 microsecond, and their rates are programmable to a resolution of one millisecond.

Linearization. Because time-critical tasks are performed immediately in response to hardware interrupts, Soft 500 ensures perfectly linearized data collection on the time axis. There is no unpredictable time skewing from the receipt of the interrupt to when sampling begins. Furthermore, rigorous anti-skewing algorithms in the background ensure that for any given channel, there will be a precise time interval between each sample, even when many different tasks over many different channels at many different rates are in effect (**Figure 2**).

Non-Maskable Interrupts. Use of the computer's non-maskable interrupt lines gives background tasks priority over the foreground tasks. In Soft500, non-maskable interrupts unconditionally direct the microprocessor to the background for immediate execution without a time-consuming handling procedure. Thus, time-critical tasks have the system's highest priority. For example, the priority exceeds that of a peripheral service request. A time-out to service a peripheral could skew background tasks dramatically.

FIGURE 2: Exact Timing in Data Sampling



Interrupts are based on precision hardware timers, and are non-maskable. Linearization algorithm maintains the exact timing of Task B.

Data Management

Soft500 supplies a wide variety of commands that make data easily accessible in the BASIC environment as BASIC variables or BASIC arrays. All data, however, are managed automatically by the software in the region of high memory above the area where the system software resides. Here, data are held in Soft500 arrays. Soft500 arrays are easily created, dimensioned, and maintained in much the same way that BASIC arrays are used. However, background input functions automatically create the appropriate Soft500 arrays, and the transfer of data is managed as part of the normal measurement procedure.

This method of storing and managing data has numerous advantages. First, there are no limitations on the size or dimensions of an array. The only limiting factor for data storage is the amount of expanded memory that can be accessed by the host computer (IBM = 640K). BASIC imposes a limitation of 64K of data memory; Soft500 provides automatic management of hundreds of thousands of data points. Soft500 arrays also include information about what the arrays contain. If they are created as the result of sampling, information about applied signal conditioning will automatically be appended so Soft500 can reconstitute and analyze data sets long after they were collected.

Software Tools for Work with Analog & Digital Input/Output

Soft500 provides a full range of input and output tasks for both analog and digital signals. In addition to the measurement and control functions that are standard to the various modules available with the Series 500, advanced functions are available to supply power and flexibility in accessing and working with acquired data. Triggering commands are included for both digital and analog thresholds. Graphing may be done in either realtime or later for stored data. Data may be stored on either floppy disks or hard disk drives, depending on the computer being used.

Triggering. Triggering programs are used to control precisely how and when particular functions within a Soft500 program will execute. Soft500 offers a wide variety of triggering commands and conditions for execution of either foreground or background tasks. Tasks may be triggered through built-in commands that respond to changes in the status of digital input or the crossing of an analog threshold. Any background task will trigger any other background task or initiate execution of the foreground once that background task has been completed. Functions may also be activated at particular times, and the use of conditional statements in BASIC allows the user to respond freely to any perceived change or condition.

Soft500 allows the user to manipulate its triggering capabilities to operate in numerous modes within and between both the foreground and the background. Thus, non-time-critical conditions can affect the drive and execution of time-critical tasks, and vice-versa. Furthermore, triggers are not limited to driving single tasks, but can activate up to 16 I/O tasks at once. Triggers can also be cycled to activate and deactivate off a single threshold or condition.

Graphing. On the IBM PC, Soft500 provides color graphing of up to 12 analog input channels using up to 3 windows. These graphing features are available in realtime during acquisition or afterwards from stored data. For digital measurements, up to 16 channels may be displayed on the screen at one time.

While Soft500 supplies a variety of graphics functions, the BASIC environment contains graphics tools to allow ornate custom displays of data in a variety of formats from histograms to screen images of the experimental setup. As BASIC functions produce screen graphics, the background can be at work acquiring data. Soft500 commands to access data as it is collected provide the means to update the BASIC graphic display even in realtime.

Engineering Units. Soft500's conversion capabilities translate data into the form appropriate for a particular application. For example, data from thermocouples and RTDs may be returned in °C, 4-20mA inputs are expressed in current, strain gage values are returned as PSI or other user-defined units, and any measurement may be returned as a voltage or a raw binary value from the A/D converter. In each case, applied amplification is noted and compensated for. With thermocouple measurements, the cold junction compensation and linearization are performed as part of the units conversion. This calculation draws on the relationship between thermocouple voltage, cold junction temperature, and degrees Celsius established by the National Bureau of Standards and included with the software system.

Command Listings

In conjunction with the statements available from BASIC, Soft500 commands provide an exceptionally powerful language for measurement and control applications program development.

ANALOG INPUT

ANIN: The fundamental analog input command for acquisition of 1 or more channels of analog data in the background at rates up to 5 samples/ms

ANINQ: For high-speed, single-ground analog input, Analog Input Quick concentrates the system's resources on one or more channels of analog data acquisition at a specified sampling speed.

ANREAD: Foreground function for taking a single point measurement of an analog input channel. Optionally, converts readings to engineering units.

SCHMITRIG: Triggers one or more functions when a specified analog input channel passes a threshold or falls within or outside a specified window.

ANALOG OUTPUT

ANOUT: The basic analog output function; one or more channels of data, residing in data arrays, is output to analog output channels at specified rates in the background.

ANWRITE: An analog output channel is set to a specified level using this single channel, single data point foreground function. Values may be specified in engineering units or in raw binary.

DIGITAL INPUT

DIGIN: Reads one or more channels of digital input, either as ports (8 channels simultaneously) or as individual channels, at selected speeds in the background.

DIGINTRIG: For digital input triggering of other functions, Digital Input Trigger will trigger on a match between the digital input specified and an indicated match value.

DIGREAD: Reads state of single digital channel or port in foreground.

DIGITAL OUTPUT

DIGOUT: Outputs data from a Soft500 array to one or more digital channels or ports at specified rates in the background.

DIGWRITE: Sets a single digital channel or port to the indicated state in the foreground.

FREQUENCY INPUT

FREQIN: The basic frequency input command, operating in the background to sample a specified channel.

FREQREAD: Foreground command which takes a single reading of a channel of frequency input.

PULSE INPUT

COUNTERREAD: Reads to current pulsecount on the hardware and software counters maintained by the PULSECOUNT command.

PULSECOUNT: Background command; initiates event counting on a specified channel of the pulse input module.

CLOCK AND TIMING

CLOCKREAD: Reads to Series 500 real time clock (hour, minute, second, day, date, month, year) in the foreground or background.

PAUSE: Suspends foreground program execution for the specified number of minutes or seconds

TIMEREAD: Reads one or more of the software timers, at a maximum resolution of 1 millisecond.

TIMERSTART: Resets and starts one or more of the software timers.

ARRAY CONTROL

ARMAKE: Creates a data array of one or two dimensions within the Soft500 memory management system.

ARDEL: Deletes a Soft500 array, deallocating memory space.

ARGETVAL: Gets a value from an array; a specified data point is retrieved from a Soft500 array, with optional conversion to engineering units.

ARLABEL: Associates a specified descriptive label of up to 255 characters with a Soft500 data array. This label is saved along with the array by ARSAVE.

ARLASTP: Returns the depth index within a Soft500 array of the last point acquired or issued by a background function.

ARLOAD: Loads a data array and any associated information into memory from disk.

ARPUT: Retrieves a BASIC array and converts it to a Soft500 array for manipulations and access using Soft 500's advanced commands.

ARPUTVAL: Puts a value into an array: a data value is stored at specified indices in a Soft500 array.

ARSAVE: Saves a data array to floppy or hard disk in binary format.

ARWRITE: Saves data array to floppy or hard disk in ASCII format.

ARSEG: Allows high speed access to Soft500 data arrays using BASIC PEEK and POKE commands.

ARSTATUS: Provides information on the attributes of a specified array, such as the dimensions, label, and last point accessed by a background function.

GRAPHING

GRAPH: A powerful graphing resource with magnification and reduction, multiple plotting of analog and digital data, scrolling and other paging modes, and multiple color options.

GRAPHRT: Realtime graphing of analog or digital data, with multiple paging or scrolling modes and full color support.

GRLABEL: Provides formatted labelling for high resolution graphic displays, including graphic windows.

HGRAPHRT: High resolution real time graphing of analog and digital I/O with windowing and user selectable scaling, labeling, and display modes.

STATISTICS & DATA ANALYSIS

INTEGRAL: Returns the integral of a Soft500 data array or section of an array as specified.

LINREGR: Performs a linear regression on any Soft500 data array or section of an array, returning various statistical results.

MEANDEV: Calculates the mean and standard deviation of any Soft500 data array or section of an array.

INFORMATIONAL COMMANDS

MEMFREE: Returns the size of the largest contiguous block of free memory in the Soft500 memory management system.

SYSTEM

BACKCLEAR: Clears all bkgd. tasks.

BACKTIME: Returns the amount of time taken up by the Soft500 background. Returns time in milliseconds with microsecond accuracy.

GO: Activates one or more bkgd. tasks set up to trigger on this command.

HALT: Halts one or more specified background tasks.

INIT: Initializes the Soft500 system parameters.

INTOFF: Disables interrupts.

INTON: Enables interrupts and sets selected rate.

IONAME: Establishes a symbolic input/output name for an analog or digital channel, and defines the channel's physical connection and parameters.

STATUS: Indicates the operating status of a background task (active, off, or waiting on trigger).

WARNON: Enables the display of warning error messages.

WARNOFF: Disables the display of warning error messages.

STEPPER MOTOR CONTROL

The following high level commands are available to manipulate stepper motors:

STPSET, STPABSLOC, STPSPEED, STPMOVABS, STPMOVERFL, STPRESET, STPMAXSP,

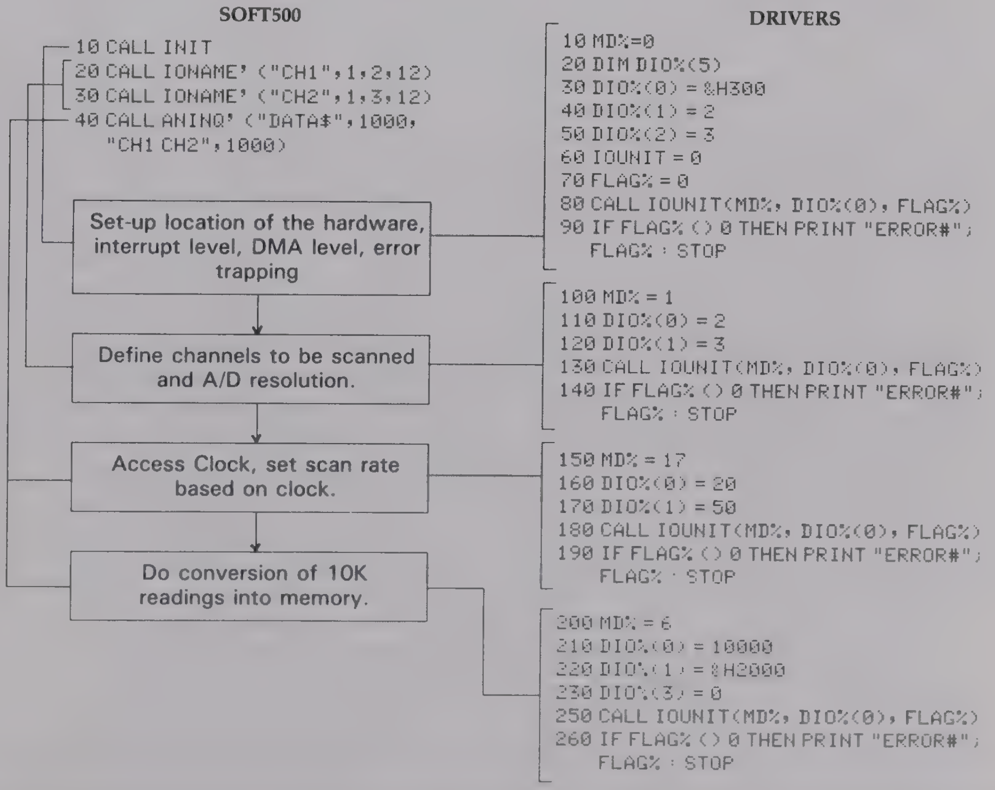
How Does Soft500 Help You?

In choosing a software environment to supply with the Series 500, our goal was to provide software that would give full access to all the power of the hardware, but would not impose a penalty of complexity. Soft500 is a simple extension to BASIC, and thus it is easy to understand and program. Underlying these simple BASIC commands, however, are assembly language subroutines that run fast and take care of timing, memory management, engineering units conversion, transfer of data arrays, and much more.

Soft500 is much more than a set of drivers. Soft500 programs are shorter, easier to implement, and easier to understand than similar programs written with drivers.

The following example shows a Soft500 program on the left and a program written for a single board data acquisition unit utilizing drivers on the right. These programs take 10,000 analog readings at 1kHz using a 12-bit A/D from channels 2 and 3 of the data acquisition unit. Both programs place the data in memory.

All of the tasks related to this example are accomplished in Soft500 with only one-sixth of the steps required for the single driver software.


Set-up location of the hardware, interrupt level, DMA level, error trapping
Define channels to be scanned and A/D resolution.
Access Clock, set scan rate based on clock.
Do conversion of 10K readings into memory.

SOFT500

```
10 CALL INIT
20 CALL IONAME' ("CH1",1,2,12)
30 CALL IONAME' ("CH2",1,3,12)
40 CALL ANINQ' ("DATA$",1000,
   "CH1 CH2",1000)
```

DRIVERS

```
10 MD%=0
20 DIM DIO%(5)
30 DIO%(0) = &H300
40 DIO%(1) = 2
50 DIO%(2) = 3
60 IOUNIT = 0
70 FLAG% = 0
80 CALL IOUNIT(MD%, DIO%(0), FLAG%)
90 IF FLAG% () 0 THEN PRINT "ERROR#";
   FLAG% : STOP

100 MD% = 1
110 DIO%(0) = 2
120 DIO%(1) = 3
130 CALL IOUNIT(MD%, DIO%(0), FLAG%)
140 IF FLAG% () 0 THEN PRINT "ERROR#";
    FLAG% : STOP

150 MD% = 17
160 DIO%(0) = 20
170 DIO%(1) = 50
180 CALL IOUNIT(MD%, DIO%(0), FLAG%)
190 IF FLAG% () 0 THEN PRINT "ERROR#";
    FLAG% : STOP

200 MD% = 6
210 DIO%(0) = 10000
220 DIO%(1) = &H2000
230 DIO%(3) = 0
250 CALL IOUNIT(MD%, DIO%(0), FLAG%)
260 IF FLAG% () 0 THEN PRINT "ERROR#";
    FLAG% : STOP
```

Quick500/Software System

Compilable Version of Soft500

Of the requests for enhancing the Series 500, the one most often heard is for a compilable version of the software. Now there are two compilable software packages for the Series 500 and the System 570: Quick500 (a compilable BASIC version of Soft500) and Lab I/O (page 41), a C version of the software.

Compilable Software. The advantage of compiling a Soft500 program is a dramatic increase in overall operating speed of a program. Interestingly, this speed increase occurs predominantly in execution of the interpreted BASIC program lines, not Soft500. This is because Soft500 commands have always been executed through fast, memory-resident code. By compiling a Soft500 program, BASIC calculations, control loops, and graphics functions can run up to an order of magnitude faster than they would under a BASIC interpreter.

Quick500. There are two advantages to Quick500: It works in the familiar BASIC environment, and it is a version of Soft 500. Working in a BASIC environment means that anyone who has had any exposure to programming can run the system. BASIC's penalty of slow processing speed, however, is overcome because Quick500 is compilable.

The command set for Quick500 is nearly identical to that of Soft500.; older Soft500 programs normally require only simple editing. Thus, the upgradability of the software is maintained.

New Capabilities. In addition to the standard set of Soft500 commands, there are a few new commands which further improve the system's performance. These commands provide "handles" to the Series 500 I/O data. The net effect is that in some applications the I/O data can be retrieved faster, in addition to the speed improvements due to Quick500's being compilable.

Microsoft QuickBASIC. The complete Microsoft QuickBASIC compiler and documentation package are included with Quick500. The QuickBASIC environment brings some of the best features of other structured compiler languages to BASIC. These include multi-line-block IF... THEN... ELSE... statements, alphanumeric labels, optional line numbers, and more. Programs can be written in a modular style for improved readability and maintainability. QuickBASIC operates in a Windows®-like screen environment, and includes a powerful word processor-like text editor, debugging tools, and support for a mouse.

The chart below compares the features and advantages of QuickBASIC to interpreted BASICA 3.1. These features contribute substantially to Soft500 in several ways: programs can be written more easily, they are compatible with a wider range of computers, and they run much faster than interpreted BASIC programs.

Comparison of Compiled and Interpreted Programs:
Microsoft QuickBASIC 2.0 vs. IBM Interpreted BASIC 3.1

	QuickBASIC 2.0	IBM BASICA 3.1
Runs on virtually any PC or AT compatible	Y	Runs on IBM products only
Produces stand-alone programs that run w/o original source code or BASICA	Y	N
Windows®-like environment	Y	N
Full-screen WP-like editor	Y	N
Built-in support for mouse for faster editing and control	Y	N
Extensive on-line help	Y	N
Powerful trace and debugging tools find and mark errors in source program	Y	N
Speed	Up to 10× faster	—
"Sieve of Eratosthenes" Benchmark	0.52 s	78 s
Support for large program & arrays	Y	64K limit
Full support of Structured Programming	Y	N
Modular programming, maintenance, and support	Y	N
Alphanumeric labels for enhanced readability	Y	N
Programming without line numbers	Y	N
Full support of BASICA's graphics and sound control	Y	Y

The Lab I/O software package supports data acquisition and control functions in the C programming language using popular C compilers such as Lattice and Microsoft. A single interrupt is supported, driven by a programmable timer in the Series 500 host interface card.

The Lab I/O package was designed to allow high performance data acquisition, providing simple primitive procedures from which highly complex applications can be constructed. A simple structure for system configuration allows the programmer or user to take full advantage of the flexibility of the Series 500 system bus. Flexible triggering mechanisms allow data acquisition to be started by external events, and facilitate the construction of fast, complex control loops.

Series 500 boards supported:
AIM1-AIM9 Analog Input Modules
AMM1 Master Measurement Module
ADM1, ADM2 Analog-to-Digital Modules
AOM1-AOM4 Analog Output Modules
DIM1 Digital Input Module
DIO1 Digital Input/Output Module
DOM1 Digital Output Module
PCM1, PCM2 Power Control Modules

SOFTWARE MODULES

The Lab I/O software driver package is grouped into several modules useful in data acquisition applications:

Configuration. During initialization of the Series 500, a text file is read which specifies several aspects of the hardware setup. The boards that are used, their slot positions in the chassis, and the switch-selectable options are specified in a simple format. In addition, each channel to be used is specified and given a name to identify the channel in the user's program. This allows the application program to be independent of the hardware configuration. A configuration sheet may be printed to verify actual hardware setup and all switch settings.

Channels are identified by the text names given in the configuration file. For efficiency, however, the **channel** module allows the user to translate the string name into an integer which is used by all the other modules to identify the channel. Channels may be input or output, analog or digital. Programmable options are specified on a channel-by-channel basis. The state of a channel may be printed in a readable format.

After the type of board and appropriate parameters for each channel are specified in the configuration file, the user need not be concerned about the particular type of the board. Every analog input channel may be read with the same command. Boards may be moved about in the chassis(and the channels as well), requiring only a change in the configuration file, without the re-compilation of any program.

Single I/O Commands. The simplest I/O command module is the **single** module. These functions read/write a single value to/from a channel. The function does the requested I/O operation immediately, and returns after the completion. Only the channel ID (an integer) is needed to completely specify the location of the channel and the programmable options utitlized.

Background Actions. The **action** module creates actions (or tasks) that will execute in the background, driven by a periodic interrupt, while the application does other computation in the foreground. Several types of actions are supported, the most important being data acquisition, where data are transferred to/from an array in memory at intervals measured in interrupt ticks. Many actions may be in progress at one time.

Triggers. The **trigger** module allows flexibile control over when an action will begin its job. An action may be set up to wait for a specified triggering event before starting a transfer. A trigger is created specifying this event (e.g., digital input bit transition from low to high). It is then cocked, enabling it to look for the occurrence of the event each interrupt period. When the event occurs, it fires, starting off all actions that are waiting for the trigger.

A useful variation is available, which allows triggers to be retriggerable. This type of trigger does not stay fired. When the triggering event occurs, the trigger fires for one interrupt period and is recocked the following interrupt, after which it may fire again. This allows an I/O transfer (or any other action) to happen each time an event occurs.

Scaling. Raw sample values may be converted to/from physical units using the **scale** module. This allows data to be dealt with in the real-world quantities that wre measured: voltage, current, and temperature. Depending on the speed and precision required, floating point or integer representation may be selected. The gains, both programmable and switch selected, of the channel are taken into account.

Miscellaneous Functions. The **background** module has commands for enabling and disabling the action interrupt. The execution time of the interrupt routines (active as well as waiting for a trigger) is available through this module.

A 32-bit **timer** is available to measure time periods. The timer is incremented at the interrupt frequency, and may be read at any time.

A time-of-day **clock** may be read for data logging. The clock may also be used for longer time period sampling. The clock has resolution of 1 second, and has a battery backup.

A provision is made for customized error/warning reporting in the **error** module. The user may specify a routine that records an error message instead of having it printed on the screen.

Accessories/Series 500 and System 570

Software, Hardware, Manuals

SOFTWARE ACCESSORIES

Help Disk: Diagnostic and calibration diskettes for the Series 500 and System 570 data acquisition systems afford the user with an easy-to-use, computer prompt troubleshooting and diagnostics of Keithley data acquisition systems.
Order Part No.:..........**500-HELP-I**

Upgrades: Soft500 upgrade kit includes current revision of software and all necessary software documentation to bring the user up to the current level of software.
Order Part No.: **500-UKIT**

HARDWARE ACCESSORIES

Terminals: Kit includes three 3-terminal and one 4-terminal Quick Disconnect Terminals for Series 500 signal conditioning and System 570 mother board interconnects.
Order Part No.: **500-TERMS**

IEEE-488 Cables: IEEE-488 standard interconnect cables, available in 1m and 2m lengths for connection of IEEE-488 instrumentation to the IEEE-488 standard bus.
Order Part No.:..........**7008-3 (1m)**
7008-6 (2m)

MANUALS

A complete set of hardware and software manuals is included with each Series 500 and System 570. Additional manuals may be ordered using the parts numbers below.

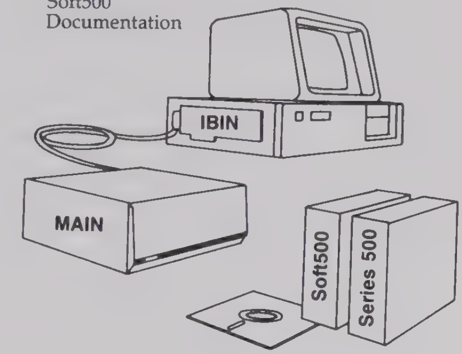
Hardware: Includes description and service sections for all Series 500 and System 570 signal conditioning modules.
Order Part No.: **500-IBMH-1**
Order Part No.: **570-IBMH-1**

Software:
Order Part No.: **500-IBMS-1**

Configuration Chart	QTY.	UNIT PRICE	TOTAL
1. Choose a mainframe or preconfigured system (see pages 102-105):			
2. Choose the additional modules that your application requires and list them here (see pages 106-128). Note that Systems 501 and 502 have 10 module slots; System 570 has one. AMM1, AIM1, ADM1, ADM2, STEP1, STEP2 are not compatible with the System 570.			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
MODULE:			
RTMDS: Real Time Monitor & Direct Storage System (occupies long slot in PC)			
3. **Soft500**, Keithley's powerful and flexible data acquisition software package, is included with every system (see pages 132-135)		N/C	N/C
4. Optional Software (see pages 136, 137, 140-145):			
5. Accessories (see above):			
TOTAL			

1. Begin with the 500-500 Starter System:

500-MAIN: 10-Slot Mainframe with Power Supply
+
500-IBIN: Interface Board
Cable
Soft500
Documentation



2. Select basic A/D conversion and analog input, 12-bit or 14-bit. NOTE: 14-bit system requires 2 cards, but includes 8 differential input channels (16 S.E.); 12-bit system on single card has 8 single-ended inputs.

12-BIT

AMM1

8-Channel S.E.
×1
MUX, PGA
12-Bit A/D

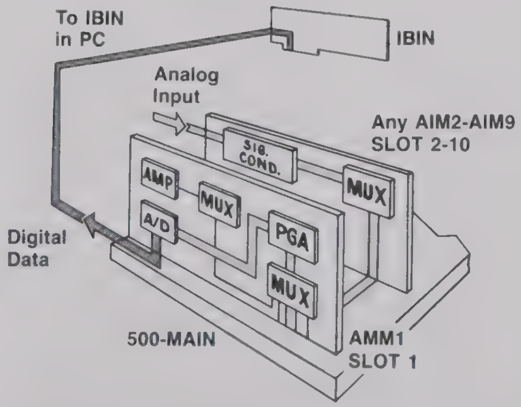
OR

14-BIT

AIM1 + **ADM2**

AIM1: 8-Channel Diff.
×1, ×10, ×100
MUX, PGA

ADM2: 14-Bit A/D



12-bit system shown (in 14-bit system, A/D converter is on separate card in Slot 2).

PGA (Programmable Gain Amplifier) is software programmable for ×1, ×2, ×5, or ×10 gain to any analog signal.

3. Add additional analog input capacity and modules as required. All signals are multiplexed, then sent to the AMM1 (or AIM1) in Slot 1 for PGA, MUX, and A/D.

ANALOG INPUT With Signal Conditioning

AIM2	32 S.E. Channels ×1
AIM3	32 S.E./16 Diff. Channels ×1, ×10, ×100
AIM4	4-Channel Isolated ×1, ×100
AIM5	4-Channel Isolated, TC Ref. ×100
AIM6	4-Channel RTD
AIM7	16-Channel Thermocouple
AIM8	4-Channel Strain Gage ×1, ×10, ×100, ×1000
AIM9	2-Channel LVDT

4. Expand with a wide variety of analog output, digital I/O, and special function modules.

Analog Output

AOM1	2- or 5-Channel 12-Bit
AOM2	1- or 2-Channel 16-Bit
AOM3	4-Chan. 0—20mA
AOM4	4-Chan. 0—10V

Digital I/O

DIO1	32-Chan. Non-Isolated
DIM1	16-Chan. Input Isolated
DOM1	16-Chan. Output Isolated
PCM1	4-Chan. Power Control
PCM2	16-Chan. Relay Drivers

Special Function

STEP1 **STEP2**	1—4-Channel Stepper Motor Control
PIM1	8-Chan. Frequency
PIM2	4-Chan. Counting
GPIB	IEEE-488 Controller
PROTO **EXTEND**	Prototyping

5. Choose the appropriate software.

Supplied:	**Soft500**	Powerful BASIC Extension
Optional:	**Quick500**	Compiled BASIC
	RTMDS	Real Time Monitor & Direct Storage
	DADiSP I	Spreadsheet Acquisition
	DADiSP II	Worksheet Analysis
	Lab I/O	"C" Callable
	ASYST	Forth-like Language
	ASYSTANT+	Menu-Driven Acquisition & Analysis
	Labtech	Menu-Driven Acquisition & Analysis

DADiSP/Software System

Data Acquisition and Digital Signal Processing

DADiSP (Data Acquisition and Digital Signal Processing) is a complete graphics-driven data acquisition and analysis software package designed for Keithley Series 500 Measurement and Control Systems and the IBM family of personal computers.

DADiSP completely automates experimental procedures in a broad spectrum of scientific and industrial applications. It is modelled after a typical laboratory notebook where each procedure is fully documented in individual LABBOOKS.

DADiSP I: Labbook structure—with each Labbook a procedure.

- **Setup:** PROTOCOL

The easy setup structure of DADiSP I is found in the PROTOCOL setup menu. A PROTOCOL contains all the information on how the experiment will be run: monitor temperature within a controlled environment, measure the voltage produced by an experimental alkaline cell, or use a current output to stimulate the activity of a laboratory animal. Whether the procedure involves collecting a signal and/or initiating one, and whether the signal is in analog or digital form, all parameters for the experiment are stored in the PROTOCOL section.

- **Storage:** DATASET

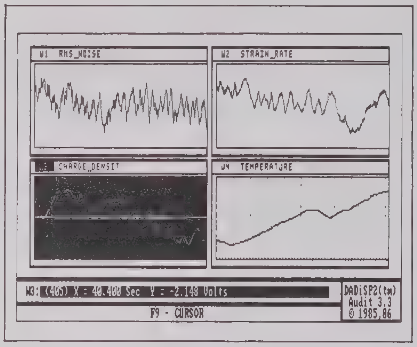
During the execution of a PROTOCOL, realtime channel data are saved to memory in a DATASET, which corresponds to the section of the lab book where the data from the experiment are recorded.

The amount of signal information that can be stored as one channel in a DATASET is limited only by the amount of floppy or hard disk memory available in the system. In addition to processing signals of varying lengths and types from the same DATASET, DADiSP allows you to access and compare data from different DATASETs.

- **Display:** WORKSHEET

In DADiSP I, each WORKSHEET consists of up to four windows. DADiSP allows you to graphically examine data by simply loading signals into these windows.

The WORKSHEET performs a variety of functions. You may load a previous WORKSHEET, save the current one, and add or remove windows. Once the WORKSHEET is loaded, you may load a signal from a DATASET into an existing or newly created window. Note that each window may contain a signal from a different DATASET. This way, results of different experiments can be compared and saved in one WORKSHEET.



```
W3: (405) X = 40.400 Sec  Y = -2.148 Volts     DADiSP2(tm)
                                               Audit 3.3
                 F9 - CURSOR                   © 1985,86
```

WORKSHEET showing four channels of data. The cursor is in window 3 where individual values from a CHARGE DENSITY signal are graphed.

You may also obtain a pop-up window for each signal containing its assigned name, date and time acquired or output, number of samples taken, sampling rate, and other details, all with one keystroke. When you enter a window containing a signal, you may use a variety of display and zooming functions. DADiSP's graphing capabilities can display grids, enlarge or compress signals horizontally or vertically, display a signal as a scatterplot or interpolated into a continuous line, or access a built-in help utility, each with a simple keystroke. A scrolling cursor may be called up to display individual data points with their x-axis and y-axis values.

DADiSP II: Advanced worksheet analysis functions.

DADiSP II offers advanced analysis functions that greatly expand the WORKSHEET capabilities of DADiSP I to analyze and display up to 64 windows from the same or different DATASETs or data files. It shares the same sophisticated graphing capabilities found in the DADiSP I WORKSHEET, allowing advanced analysis in an easy to interpret format.

The advanced analysis functions let you execute complex calculations on data and perform mathematical routines with immediate graphic results. The functions range from standard arithmetic functions of addition, subtraction, multiplication, division, and exponentiation to advanced trigonometric and hyperbolic functions, statistics, and frequency domain transformations.

PROTOCOL NAME: The name of the experiment

SCAN RATE (Hz): The rate at which data from a particular channel will be input or output, e.g., "50.000 Hz".

START: Triggers the start of the entire experiment

STOP: Triggers the stop of the experiment

COMMENT: General information on the experiment as needed

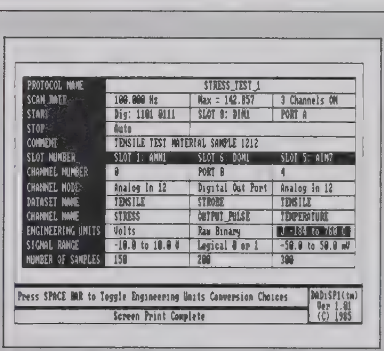
SLOT NUMBER: Location in the mainframe of the indicated module

CHANNEL NUMBER: Number of the channel being accessed

CHANNEL MODE: Selects on/off mode of the channel and A/D resolution

DATASET NAME: Name of the DATASET in which information from this channel will be saved

CHANNEL NAME: Title given to the channel



PROTOCOL NAME	STRESS_TEST_1		
SCAN RATE	100.000 Hz	Max = 142.857	3 Channels ON
START	Dig: 1101 0111	SLOT 0: DIM1	PORT A
STOP	Auto		
COMMENT	TENSILE TEST MATERIAL SAMPLE 1212		
SLOT NUMBER	SLOT 1: AMM1	SLOT 6: DOM1	SLOT 5: AIM7
CHANNEL NUMBER	0	PORT B	4
CHANNEL MODE	Analog In 12	Digital Out Port	Analog In 12
DATASET NAME	TENSILE	STROBE	TENSILE
CHANNEL NAME	STRESS	OUTPUT_PULSE	TEMPERATURE
ENGINEERING UNITS	Volts	Raw Binary	J -184 to 760 C
SIGNAL RANGE	-10.0 to 10.0 V	Logical 0 or 1	-50.0 to 50.0 mV
NUMBER OF SAMPLES	150	200	300

```
Press SPACE BAR to Toggle Engineering Units Conversion Choices   DADiSP1(tm)
                                                                 Ver 1.01
                     Screen Print Complete                       (C) 1985
```

PROTOCOL setup with engineering units selected.

ENGINEERING UNITS: Units in which data from this channel will be expressed

SIGNAL RANGE: Full scale input range for this channel, accounting for the A/D input range. Software automatically selects the PGA gain.

NUMBER OF SAMPLES: Number of samples to be taken on this channel

Software System/**DADiSP**

Data Acquisition and Digital Signal Processing

BASIC MATHEMATICAL FUNCTIONS

DADiSP II supports five-function mathematics (+, −, ×, /, ∧) as well as a broad range of additional functions. These functions may be applied to integers, real or complex numbers, or windowed signals (Wn) with equal facility.

ADVANCED MATHEMATICAL FUNCTIONS

DADiSP II supports a number of more advanced mathematical functions including trigonometric, logarithmic, and other functions. These can be applied to any valid signal or scalar or signal-scalar expression. When applied to a signal, they are applied successively to each point of the signal and the resulting signal is placed in the current window. When applied to scalars (integers, real numbers, or complex numbers), the resulting value is displayed at the bottom of the screen.

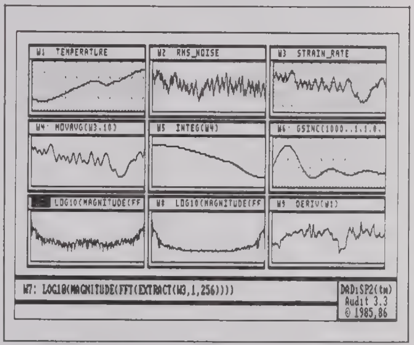
Calculus Functions are for calculating derivatives and integrals of signals. Since the signals are discrete, DADiSP provides a means of performing left derivative and right derivative calculations. Four of these functions (DERIV, LDERIV, RDERIV, INTEG) take one signal as an argument and return a new one. AREA takes two additional arguments, the starting point and the ending point within the signal. Note also that AREA returns a scalar whereas the other four return signals. The algorithm for calculating the integral is a modification of Simpson's Rule; it is more accurate than a simple trapezoidal approximation.

Statistical Functions provide statistical information about a signal (or two signals in the case of LINREG2). MEAN and STDEV return appropriate values which can be nested in more complicated expressions. STATS does not return a signal, but displays both the mean and the standard deviation at the bottom of the screen. LINREG and LINREG2 display the regression coefficients and then create a new signal: the line generated by the linear regression. This is useful for overplotting. Finally, AMPDIST generates a new signal which is really a bar graph of the distribution of the values of a signal. It takes a second argument, a real number, which is the DELTA X variation.

Signal Analysis. DADiSP II provides functions for frequency domain analysis. Fourier analysis is provided with both the Discrete Transform and the much faster Fast Fourier Transform. The FFT will not operate on a signal unless its length is a power of 2. PARTSUM creates a new signal of the partial sums of the input; MOVAVG provides a smoothing function; SUMS adds any number of signals together; and AVG takes the point-by-point average of a group of signals.

Signal Editing Functions allow the creation of new signals from old ones. EXTRACT creates a new signal by extracting a part of another one. If the new signal contains points not in the argument signal, then EXTRACT pads the argument with 0.0's. REVERSE simply reverses the given signal. CONCAT will concatenate any number of signals together. PROTECT will protect a signal from propagation. PROTECT takes a second argument which is a new string to display instead of the formula string.

Signal Generation Functions. The DADiSP II Worksheet enables the production of a variety of waveforms through the use of the functions beginning with the letter G. An endless variety of waveforms can be synthesized through combionations of these functions (including ARC and hyperbolic, e.g., GASINH for hyperbolic arcsine).



```
W7: LOG10(MAGNITUDE(FFT(EXTRACT(W3,1,256))))
```

WORKSHEET displays 9 windows with different analytical functions.

DADiSP SYSTEM REQUIREMENTS

HARDWARE: IBM PC or PC-XT, with a minimum of 512 KB RAM; IBM-DOS 2.0 or above; color monitor; 8087 co-processor (optional); one 360 KB floppy disk drive; a second disk drive, either floppy or hard disk; Keithley Series 500 Workstation Measurement and Control System; IBM graphics card.

SOFTWARE: DADiSP I: STARTUP diskette, SYSTEM diskette, Soft-500 Version 3.0 software diskette. DADiSP II: STARTUP diskette, SYSTEM diskette.

COMPATIBILITY

HARDWARE: DADiSP software supports the following Series 500 modules: AMM1, AIM1 through AIM7, ADM1, ADM2, AOM1 through AOM4, DIO1, DIM1, DOM1, PCM1, PCM2.

SOFTWARE: DADiSP software provides import and export utilities for Lotus 1-2-3, Macmillan ASYST, Soft500, and most ASCII formatted files.

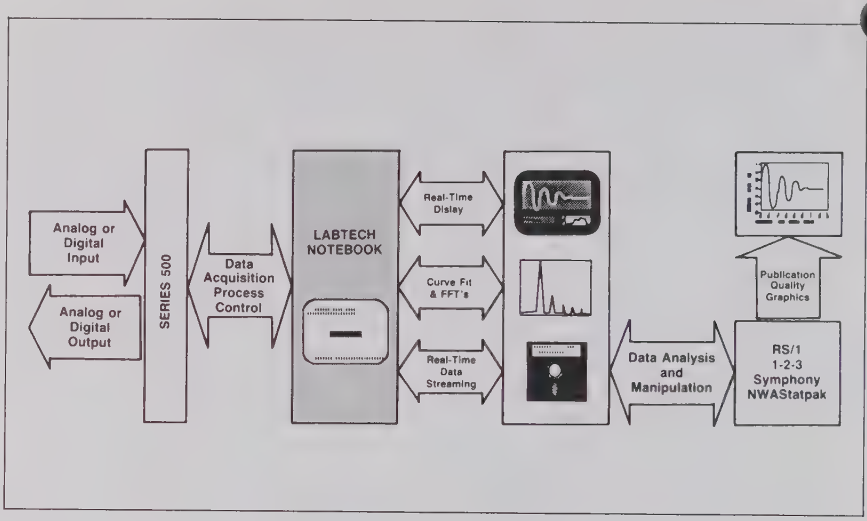
I/O SPEED (Analog Input, Analog Output, Digital Input, Digital Output): 1kHz.

IBM PC and PC AT are trademarks of the International Business Machines Corporation. Lotus 1-2-3 is a trademark of the Lotus Corporation. ASYST is a trademark of Macmillan Software Company, Inc. DADiSP is a trademark of DSP Systems.

LABTECH NOTEBOOK/Software System

Software for Data Acquisition & Control

- **Menu-driven software in the style of popular spreadsheets**
- **Interfaces to other programs for analysis, graphics, and data base management**
- **Process control—open or closed loop**
- **Fast Fourier Transforms: real and complex waveforms, forward and inverse FFTs**
- **Advanced nonlinear curve-fitting function: up to 10 parameters and 10 independent variables**
- **Foreground/background operation—run other PC programs during data acquisition and control**
- **Real Time Access™ option pipelines data directly to the foreground program**



LABTECH NOTEBOOK, an integrated, general purpose software package for data acquisition, process control, monitoring, and data analysis, runs on the IBM PC, XT, AT, and other PC compatibles. Because of its fast and easy-to-use menu system, LABTECH NOTEBOOK requires no programming. When interfaced with analysis programs such as 1-2-3, Symphony, NWAStatpak, or RS/1, NOTEBOOK increases laboratory research productivity the same way personal computers increase productivity for the office.

Flexibility is a key feature of LABTECH NOTEBOOK. To this end, each channel can be set up with different characteristics. Sampling rates may vary from channel to channel, or for each channel at different times during a run. Data acquisition may take place as soon as the program starts, or may be triggered on or off by an external source. LABTECH NOTEBOOK can linearize thermocouple data in real time. The time-of-day or time-in-experiment can be noted with each data sample taken. Data from multiple channels can be combined in several ways, and other calculations can be done in real time, producing new "channels" of transformed data.

For control functions, open- and closed-loop control algorithms are readily implemented. In open-loop mode, the waveform signal is clocked out automatically during the run. For closed-loop control, PID (proportional-integral-derivative), "bang-bang" (on/off), and "alarm" loops can be set up.

LABTECH NOTEBOOK includes two sophisticated analytical routines: nonlinear curve-fitting, and Fast Fourier Transforms (FFTs). These programs are designed to take advantage of the time-saving 8087 or 80287 floating point processors, if they are present in the PC, but do not require them. The curve-fit function uses an iterative routine (Powell's Method) to fit an arbitrarily complex model (up to 10 parameters and 10 independent variables) to the collected data. The FFT function provides a powerful tool for signal processing analysis, accomodating both real and complex input waveform data. In addition, the FFT function can be used to calulate power spectra.

By interfacing NOTEBOOK with an analysis program or spreadsheet such as 1-2-3, Symphony, RS/1, MathCAD, or NWAStatpak, the user may go from data collection to the final report without ever writing down or keying in a single piece of data. Data files may be automatically imported into a worksheet or table for reduction and analysis (integration, differentiation, logarithmic conversion, etc.), statistical comparisons, and preparation of publication-quality graphics. Depending on the software chosen, database management and word processing are also available.

Software System/**LABTECH Real Time Access**

Real Time I/O for Non-Real Time Programs

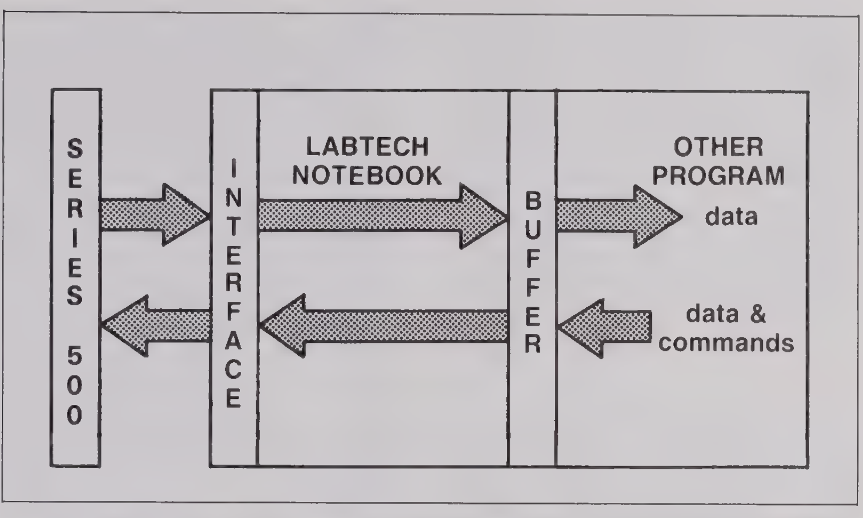
- **Provides for real time acquisition of data into the application program**
- **Can be used with popular spreadsheets, data bases, and analysis programs such as 1-2-3®, Release 2, Symphony®, and dBASE III®**
- **Programs access real time data through standard file I/O statements**
- **Allows the program or operator complete control over the data acquisition environment**

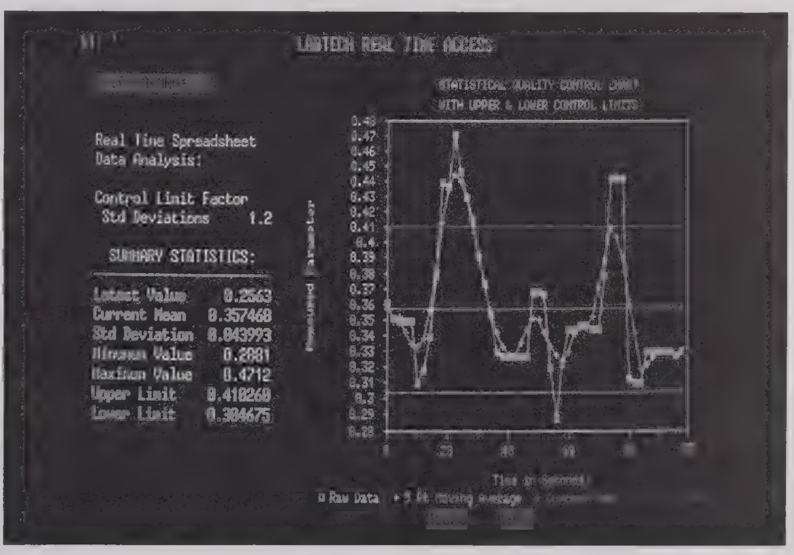
LABTECH NOTEBOOK has for some time featured the unusual capability of operating as a real time multitasking subsystem on a personal computer with PC/MS-DOS. NOTEBOOK can be "in the background" carrying out a complex schedule of data acquisition and control while while the user at the console is running some other DOS application program. Until the advent of Real Time Access, the two programs ran independently, and did not communicate with each other.

Real Time Access provides for that interprogram communication. It allows the foreground application to access real time data being acquired simultaneously by NOTEBOOK.

Virtually any existing application program that can access files can access data acquired in real time from analog or digital instrumentation by LABTECH NOTEBOOK. It need not have been specially written to work with the LABTECH Real Time Access' virtual device, since the device is indistinguishable from an ordinary ASCII file from the application program's point of view. Existing spreadsheets, statistical analysis programs, quality control programs, graphics programs, and more can gain real time data acquisition capabilities.

The application program may freely input real time data acquired by NOTEBOOK runtime code by ordinary file reading operations. The program also may optionally write a command stream modifying NOTEBOOK's acquisition and control parameters.




LABTECH REAL TIME ACCESS

Real Time Spreadsheet
Data Analysis:

Control Limit Factor
Std Deviations 1.2

SUMMARY STATISTICS:

Latest Value	0.2563
Current Mean	0.357468
Std Deviation	0.043993
Minimum Value	0.2881
Maximum Value	0.4712
Upper Limit	0.410260
Lower Limit	0.304675

Lotus Symphony (above) and other applications can now analyze and chart scientific and industrial process data in real time with LABTECH Real Time Access.

ASYST/Software System

Scientific Software

- **Interactive or fully programmable operation**
- **Built-in sophisticated analysis functions**
- **Automatic graphics with modifiable defaults**
- **Multiple graphics windows**
- **All capabilities completely integrated**
- **Unprecedented speed on the PC with integral use of the 8087 math coprocessor**

ASYST scientific software for the PC provides data acquisition, analysis, and graphics in a completely integrated system. It supplies sophisticated analytical capabilities, precision, and speed previously found only in mainframe and minicomputers.

ASYST is four completely integrated modules:

Module 1: System/Graphics/Statistics, which establishes the system; includes arithmetic and basic statistical functions, all graphics capabilities, and a programming language.

Module 2: Analysis

Module 3: Data Acquisition

Module 4: GPIB/IEEE-488

Modules 1 and 2 must be included in every system; 3 and 4 are optional.

ASYST can be used by someone with minimal computer background to accomplish tasks which would require sophisticated programming in other systems or languages. It provides the capability to perform many advanced tasks in a straightforward way, as well as the means to customize and extend the system.

Level 1: Advanced Calculator. At its simplest and easiest-to-use level, ASYST can be used much like a programmable calculator, providing basic mathematics, arithmetic, statistics, trigonometry, and other functions.

Level 2: Command-Driven Program. ASYST, even before being customized, is a sophisticated, comprehensive data reduction tool. All ASYST acquisition, analysis, and graphics functions can be command-driven. This allows for more flexibility than a menu-driven architecture. Command names accurately describe the routines they execute.

Level 3: Programming Language. Sequences of ASYST words may be linked together to form simple user-defined programs. This allows ASYST to be customized to a great variety of specific applications, even by non-programmers.

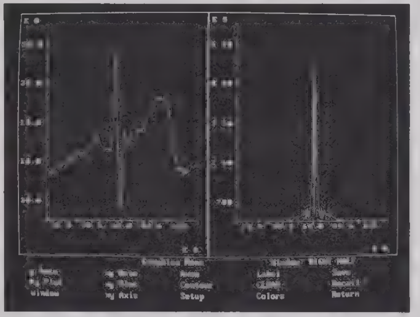
HARDWARE REQUIRED:
- IBM PC, XT, AT, or DOS 2.0/2.1/3.0/3.1 compatible
- Two or more drives (including one double-sided floppy drive)
- 512K memory (640K recommended)
- 80807 or 80287 coprocessor
- IBM Color Graphics Board, IBM Enhanced Color Graphics Card (with 64K to 256K graphics memory), or Hercules Graphics Card

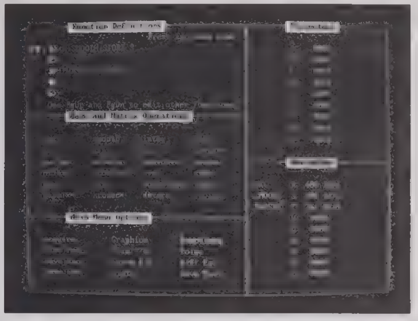
SOFTWARE: Each system consists of one Master 5¼-in. double-sided floppy diskette; Help System diskette; backup Master diskette; tutorial manual; reference manual; and a comprehensive index.

Software System/**ASYSTANT**

Ready to Run Scientific Software

- **Interactive, menu-driven data acquisition, data analysis, and signal processing**
- **Differential equations**
- **Curve fitting**
- **Plotter graphics support**





ASYSTANT is a stand-alone, full-functioned software package for scientific data analysis, graphics, statistics, and optional data acquisition. It is completely menu-driven and requires no programming. ASYSTANT's analysis structure is built around a "desk calculator" that operates directly on waveforms and datasets, and supports a wide variety of high-level functions such as FFT, power spectrum, and matrix inversion and smoothing, as well as basic arithmetic and trigonometric functions.

Other menus support curve fitting, presentation graphics, statistics, polynomials, differential equations, file I/O, automatic waveform generation, file-based processing, and graphics-based waveform processing. A function key definition menu lets the user specify sequences of calculator commands for automatic execution (macro support).

Two versions of the program are available: ASYSTANT, the basic package, and ASYSTANT+, which adds data acquisition to all of the capabilities of ASYSTANT.

HARDWARE REQUIRED:

- IBM PC, XT, AT, H-P Vectra, or DOS 2.0/2.1/3.0/3.1 compatible
- Two or more drives (including one double-sided floppy drive)
- 640K memory
- 8087 or 80287 coprocessor
- IBM Enhanced Color Graphics Card (with 64K to 256K memory), IBM Color Graphics Board, H-P Multimode Video Adapter, AT&T High Resolution Monochrome Graphics Card, or Hercules Graphics Card

SOFTWARE:

ASYSTANT: Each system consists of four 5¼-in. DSDD floppy diskettes: System, Key, Analysis, and Help; and one documentation manual.

ASYSTANT+: Six 5¼-in. DSDD diskettes: System, Key, Help, Analysis, Acquire 1 and Acquire 2; and one documentation manual.

DATA TRANSFER MODES

Strip Chart Recorder: Provides continuous real time display and throughput to disk on up to 8 channels.

Transient Recorder: Captures two windows of data surrounding a user-defined event trigger on up to 8 channels, with post-capture graphical display.

XY Recorder: Provides continuous display in an X versus Y plot of two A/D channels with continuous throughput to disk.

Data Logger: Continuous low speed data acquisition with throughput to disk and real-time conversion to engineering units. Real-time printout to screen and/or printer. Up to 4 stages and 6 alarm conditions and messages can be defined.

High Speed Recorder: Up to 16 channels of data acquisition with post-acquisition graphical display and file I/O.

Signal Averager: Similar to the high speed recorder, except that the running average is automatically calculated across scans.

Function Generator: Provides D/A output from a waveform array (created in waveform generator or any other data array). Operates concurrently with many data acquisition modes.

Waveform Scroller: Similar to the Strip Chart Recorder but supports the RTMDS Graphics Accelerator Card.

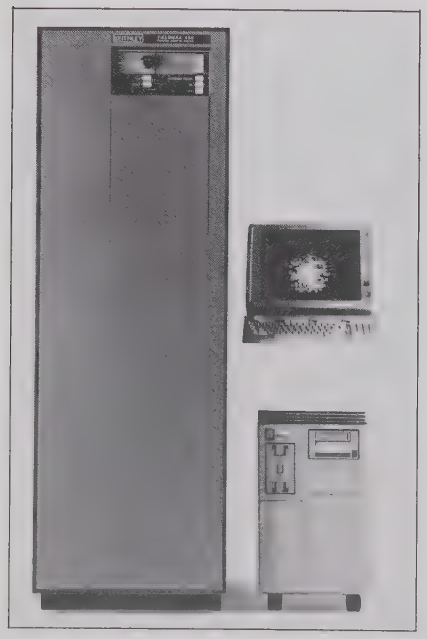
Semiconductor Testing Solutions From the Process Monitoring People at Keithley Systems

The semiconductor fabrication process is an intricate, complex, and demanding environment. As semiconductor manufacturers develop smaller geometries and reach into the sub-micron region, the requirement for accurate process monitoring becomes a challenging necessity.

Backed by more than 40 years of precision measurement technology, Keithley Systems stands ready to meet the most exacting process monitoring demands. Our ever-expanding line of semiconductor test systems provides the hardware, software, and support services that semiconductor professionals worldwide have come to depend on.

A New Technology System

The new **Yieldmax 450 Process Monitor System** incorporates new technologies such as simultaneous V/I force and differential measurement in a single instrument, new VME based instrument controller, and precise matrix switching to provide more accurate process related information to increase wafer yields. The system consists of the Yieldmax instrumentation package, a DEC VAX applications processor, and system terminal.



YIELDMAX 450 Process Monitor

Parts In The Package. The major advances in system speed, accuracy, and resolution are found in the Keithley modular instrumentation package. The new Matrix is a sophisticated switching system that you can easily configure to any measurement need. The Matrix has substantial improvements in internode leakage, leakage pin-to-ground, and offset current. Another. major new feature is the Yieldmax 450's use of both standard and high resolution pathways. Each pathway is an independent node which can be connected to any of the system instrument terminals as well as any DUT pins, thus providing maximum flexibility for any test configuration.

Accuracy control is provided by a System Reference Unit which is the heart of the new automatic diagnostic and calibration utility. This single-board plug-in module automatically calibrates the system and eliminates inaccurate readings caused by drifting over time. The system reference module may be removed from the cabinet, shipped to a calibration lab, and then re-inserted into the system.

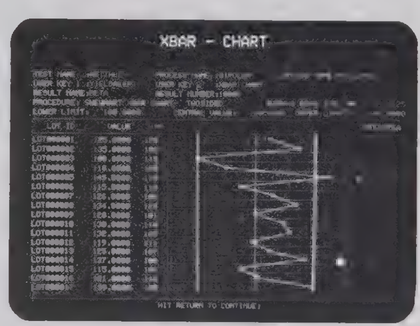
The Yieldmax 450 also uses more compact and efficient modules for voltage/current, measurements, and forcing. Single board VIMS modules can perform all these functions simultaneously as well as differential and range independent force and measurement.

The applications processor is a Digital Equipment Corporation (DEC) VAX computer system. This means that virtually any configuratin and networking requirement you have can be accommodated.

The instrument processor is based on VME (Versa Module Europe) architecture, and uses the Motorola 68020 microprocessor as the controller. This architecture puts more computer power into instrument control, and makes Yieldmax the most intelligent instrument package available today.

Programs for Productivity. The hallmark of Keithley parametric test systems has always been an extensive line of software development tools. The Yieldmax 450 maintains this tradition with improved or entirely new software packages:

Yield-Alert: Statistical Process Control Software that lets you detect flaws in the production process and control quality in real time. With Yield-Alert software for the Yieldmax 450, you'll be warned of process problems in time to do something about them.



Yield-Alert output control chart

EasyTest: An automatic program generator that uses convenient menu-driven prompts and HELP screens. It takes you from test program development to a completed program without having to use cumbersome computer language and operating system commands.

QuickTest: This software provides an enhanced development environment that aids in test module design. This interactive utility lets you set up all the parameters needed, so all you have to do is provide the device under test, push a few buttons on the keyboard, and receive immediate test results.

Parametric Test Library: A new set of test routines accessible from EasyTest menus performs common parameter tests. You can quickly perform common general purpose tests such as resistivity and capacitance, as well as tests for Bipolar, MOSFET, JFET, and MESFET active devices.

Point… Click… Results

The OMEGA 220 is a total resistivity measurement and analysis system. Hardware and software developed to provide you with accurate, flexible, and fast measurement of test wafer sheet resistance, bulk resistance, or carrier concentration.

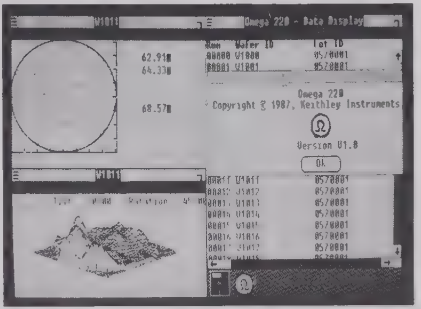
The IBM PC-AT, together with highly accurate OMEGA 210 four-point probe unit and measuring unit, gives you the knowledge you need to increase yields and profits. Our precision instrumentation and advanced software puts you in control of the process, taking those critical initial resistance measurements quickly and accurately that will determine go or no-go decisions for that wafer lot. OMEGA will let you know if incoming wafer lots meet your specification or if your fabrication processes are producing quality wafers.

Easy to Use… And We Mean It! No matter what the level of accuracy or repeatability of any instrument, if the operator requires special training or specialized instructions, you lose the competitive edge, time, and flexibility.

Keithley's OMEGA resistivity software package provides true "user friendly" instrument control. Operating in a multitasking windows environment, OMEGA is easy on engineers and operators alike. There is no need to learn a complicated programming code, as no programming is required. Pull-down and pop-up menus allow for easy test program setup, execution, and instrument control. OMEGA hardware and software control inputs can be made via the keyboard or the mouse.

Flexibility. OMEGA allows data collection, analysis, and data communications to be performed simultaneously.

OMEGA's exclusive multitasking feature gives you the opportunity to view a number of different variables, compare information, transfer or combine data, all at the same time. The mouse makes the process even faster and easier.



OMEGA 220 multitasking software

Data are displayed the way you require, in high resolution color graphics. View or print data as 2D contours, 3D plots, diameter scans, and various process control charts. The results can be represented in terms of slice/bulk/sheet resistivity, thickness, V/I, or carrier concentration. OMEGA software gives you the ability to generate reports about characteristics of a single wafer, report trend data across lots, and correlate restivitity data with other process data.

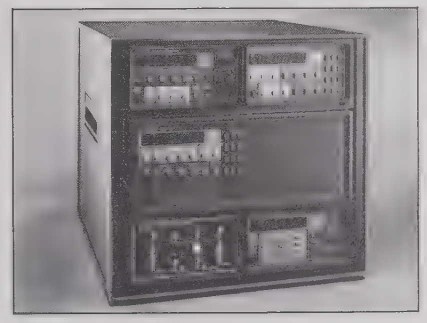
Since OMEGA is a Keithley product, you have the ability to interface with a process monitor like the Yieldmax 450, which allows you the opportunity to develop even more accurate control charts to keep your entire process in control. OMEGA is a powerful process management tool.

OMEGA 220 resistivity analysis system

GaAs Testing Made Easy

The Keithley System 110 is a computerized test system for Hall effect, resistivity, and mobility measurements in bar and wafer samples of gallium arsenide and other wide band-gap semi-insulating materials.

The System 110 is fully integrated, tested, and installed by Keithley. You can concentrate on testing rather than hardware/software development. A test box (dummy sample) is provided to verify system operation. A complete software package is included to perform test measurements and system diagnostics. The measurement programs automatically calculate the Hall coefficient and carrier mobility from resistivity and Hall voltage measurements. You can select between configurations for van der Pauw or bar-type samples.



System 110 Hall Effect tester

Control and Programming of the System 110 have been simplified through the use of the IEEE-488 bus standard and the inclusion of complete software source listings with the system. Program source codes are supplied in BASIC, and are designed to run on the IBM personal computer.

A Complete, Packaged System. The Keithley System 110 is delivered as a complete, packaged unit including all cabling, software listings, and a comprehensive hardware and software manual. It is backed by applications and field service personnel who can provide phone assistance and on-site service. Keithley can supply the System 110 as a turnkey system including electromagnet with power supply, controller and gauss meter, and a closed loop helium cryogenics system with controller.

Keithley's Radiation Measurements Division has become a respected name in the field of industrial and medical dosimetry by combining proven electrometer technology with advanced ion chamber designs. Today, the Radiation Measurements Division continues to provide high quality products in the tradition established by Joseph Keithley.

Our Current Product Line

We supply an expanding line of precision dosimeters, ion chambers, logarithmic picoammeters, exposure controls, X-ray quality assurance and service instruments, and radiation survey and monitoring equipment.

In addition, our Engineering Department welcomes inquiries for design and manufacture of custom instrumentation, OEM devices, and other products.

The Radiation Measurements Division serves five major application areas: X-ray quality assurance, medical physics, health physics, field service/calibration, and special OEM applications.

X-Ray Quality Assurance

Our newest product for easy quality assurance testing of X-ray equipment is the Keithley **DARTT™ System (Model 35090)**. The DARTT™ System (Digital Advanced Radiological Test Tool) is a reasonably priced radiological test system that runs on your IBM compatible PC. The DARTT™ System tests beam reproducibility, half-value layer, kV effective, fluoroscopic exposure rate, and linearity. The System takes measurements, performs the necessary calculations, and stores and prints test results in a handy, comprehensive report form. A special option allows users to view the true kV waveforms on the PC monitor.

The Radiation Measurements Division has other proven products for non-invasive evaluation of X-ray machines:

DARTT™ System/Model 35090

- The **Model 35075 Digital kVp Meter** allows safe, accurate measurements of voltage applied to the X-ray tube, without disturbing high-voltage cables.

The X-ray beam is differentially filtered before it reaches the sensing stage of the instrument. A ratio of the sensor readings from the heavily filtered and lightly filtered beam areas is converted into a kVp signal.

The 35075 provides a convenient, direct digital display of kVp for hospital quality assurance procedures, and we offer a waveform output option which displays a true kV waveform signal on a storage oscilloscope.

- The **Model 35065 Digital Dosimeter** is convenience itself for quick-check evaluation of X-ray machine performance. The X-ray beam is collimated to the active area of the built-in ion chamber and an exposure is made.

The digital display reads out in milliroentgens in the exposure mode and roentgens/minute in the exposure rate mode. A half-value layer filter kit, carrying case, data tablet, and notebook are optional accessories.

Medical Physics

Our best-known therapy products are our precision dosimeters. The **Model 35617 Digital Dosimeter System** is one of the most versatile dosimeters available today for therapy and research applications. All front panel controls are programmable, and its bias supply conforms to the AAPM TG-21 recommendations. In addition, the Model 35617 is IEEE-488 interfaceable for automated operation.

The **Model 35614 Digital Dosimeter** has a built-in, adjustable bias supply and rechargeable battery or line operation for extra flexibility as a research/clinical tool. The 35614 has resolution of 1×10^{-13}C on the CHARGE setting, with a full scale range of 20×10^{-8}C in three ranges. A Farmer-type ion chamber for use with both Models 35617 and 35614 is available separately.

The **Model 35060 Digital Constancy Meter** checks the consistency of radiation output of therapy machines such as linacs, cobalt therapy machines, and high-intensity X-ray generators.

The 35060 uses an ion chamber detector, which is much more stable than diode detectors that typically show decreased accuracy over time due to repeated exposure of the diodes to radiation.

We offer our line of high-quality **96000-Series Ion Chambers** for quality assurance testing, dosimetry, and low-intensity scatter radiation monitoring.

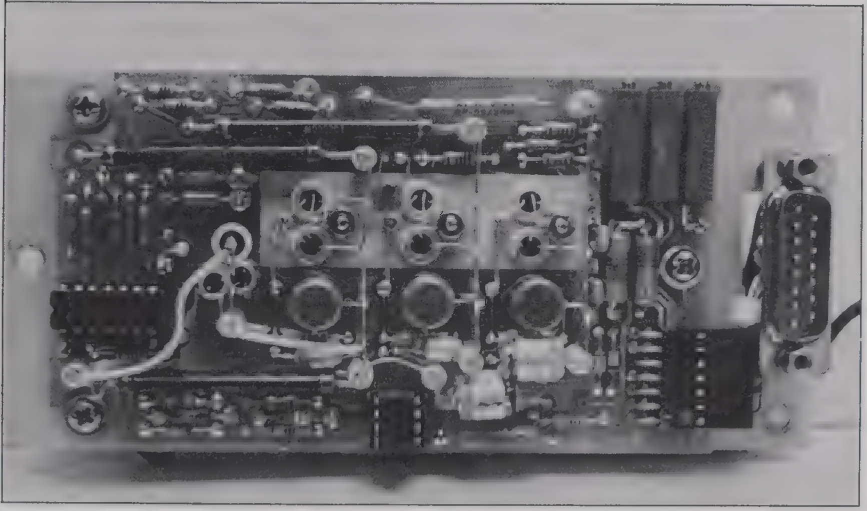
Health Physics

The **26000-Series Log Picoammeters** are used in area monitoring at nuclear power generating and research reactor facilities. These instruments are available with customer-installable options of bias supplies and alarm trips.

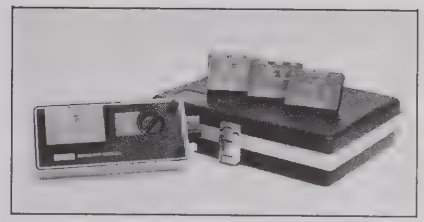
A recent addition to the 26000-Series is a special logarithmic amplifier module with an extended range from 10^{-14}A to 10^{-3}A in a single logarithmic span. This module retrofits into standard 26000-Series logarithmic picoammeters, along with the user's choice of one of two front panel scales: an 8-decade span from 0.01mR/hr. to 1000R/hr., or an 8-decade span from 10^{-14}A to 10^{-6}A. The radiation scale is used with our 6-liter or 12-liter vented-air ion chambers for area monitoring.

Our **36000-Series Survey Meters** are used in health physics programs in clinical settings such as isotope storage areas and monitoring of brachytherapy patients.

These survey meters include the **Models 36150** and **36155** (our integrating survey meter with its standard and beta window versions, respectively) and the **Model 36350**, our integrating survey meter with readout in millisieverts, the International Metric System unit for radiation dose.



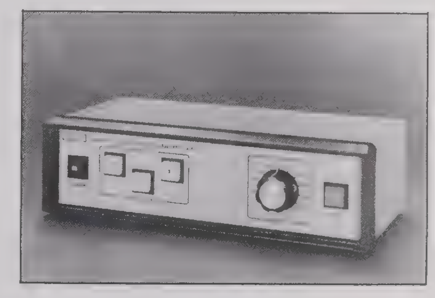
Special extended-range log module



Model 35080 kVp Divider—part of the 10500 Service Kit

Field Service/Calibration

Our **X-Ray Field Service Kit (Models 10500/600/700)** form the core of an extensive line of test and calibration equipment intended for the X-ray service organization. The multiple model numbers represent versions of the kit which vary in equipment content. Contents may include paired ion chambers with NBS-traceable calibration, our popular **Model 35050** Service Dosimeter, **Model 35080** non-invasive kVp Divider, and standard filter pack set.



Model 75200 Radiographic AEC

With over ten years of experience building phototimers, we've added automatic exposure controls (AECs) to our product line. Both **Model 75100** (mammographic AEC) and **Model 75200** (radiographic AEC) are designed to reduce retakes, minimize patient exposure, and enable high throughput operation of X-ray units by providing consistent film densities. Both units are easy to install and calibrate, and the control board may be mounted either inside an existing generator panel or in a separate instrument case.

A special feature of our AECs is multiple screen/film compatibility: A digital kV compensation network with up to four screen/film combinations is provided by a PROM.

Index

100
155 Microvoltmeter/Null Detector 62
169 Portable/Bench DMM 8
175 Autoranging DMM 10
177 Microvolt DMM 9
179A TRMS DMM 9
181 Digital Nanovoltmeter 60
193A System DMM 19
194A High Speed Digitizer 21
195A Digital Multimeter 14
196 System DMM 16
197 Autoranging Microvolt DMM 12

200
220 Programmable Current Source 65
224 Programmable Current Source 67
228 Programmable Current/Voltage Source..........................68
230 Programmable Voltage Source 65
247 High Voltage Supply 70
261 Picoampere Supply 71
262 Low Thermal Voltage Divider 61

400
427 Current Amplifier 45
480 Digital Picoammeter 46
485 Digital Picoammeter 46

500
Series 500 Data Acquisition System 102
System 570 Data Acquisition Workstation 104
580 Micro-Ohmmeter 25

600
602 Solid State Electrometer............44
610C Electrometer 44
614 Digital Electrometer................38
617 Programmable Electrometer/Source .36
619 Digital Electrometer/Multimeter 40
642 LNFPA Digital Electrometer 42

700
705 20-Channel Scanner 74
706 100-Channel Scanner 74

1000
1010 Rack Mounting Kit 85
1017 Rack Mounting Kit 85
1019A Fixed Rack Mounting Kit (619).....85
1019S Slide Rack Mounting Kit (619) 85
1019A-1 5¼-in. Single Fixed Rack Mounting Kit...................85
1019A-2 5¼-in. Dual Fixed Rack Mounting Kit...................85
1019S-1 5¼-in. Single Slide Rack Mounting Kit...................85
1019S-2 5¼-in. Dual Slide Rack Mounting Kit...................85

1300
1301 Temperature Probe 86

1400
1481 Low Thermal Input Cable 86
1482 Low Thermal Input Cable 86
1483 Low Thermal Connection Kit 86
1484 Refill Kit for 1483.................86
1485 Female Low Thermal Input Connector 86
1486 Male Low Thermal Input Connector 86
1488 Low Thermal Shorting Plug 86
1489 Battery Pack 86

1500
1506 Low Thermal Input Cable 86
1507 Low Thermal Input Cable 87

1600
1600A High Voltage Probe...............87
1651 50-Ampere Shunt 87
1681 Clip-On Test Lead Set 87
1682A RF Probe 87
1683 Universal Test Lead Kit 87
1684 Hard Shell Carrying Case (Bench DMMs)..................87
1685 Clamp-On Current Probe 87
1686 Vinyl Carrying Case (Bench DMMs)..................87
1691 General Purpose Test Leads 88
1699 Spare Parts Kit (169).............88

1700
1751 Safety Test Leads.................88
1753 IEEE-488 Interface (175) 88
1754 Universal Safety Test Lead Kit.....88
1755 Calibration Interface 88
1758 Rechargeable Battery Pack (175, 485) 88
1759 Spare Parts Kit (175).............88
1766 Battery Eliminator (169) 88
1779 Spare Parts Kit (177).............88
1788 Rechargeable Battery Pack (177, 179A, 480) 88
1792 Isolated BCD Output (177, 179A, 480) 89
1793 IEEE-488 Output (177, 179A, 480) 89

1800
1815 Maintenance Kit (181).............89

1900
1930 TRMS AC Volts Option (193A) 89
1931 Current Option (193A) 89
1938 Fixed Rack Mounting Kit (193A, 194A) 89
1939 Slide Rack Mounting Kit (193A, 194A) 89
1942 External Sample Trigger Cable (194A) 89
1944A Channel 2 Option (194A)..........89
1950 TRMS ACV, ACA, DCA Option (195A) 89
1951 Input Adapter Box (195A) 90
1972 Analog Output/IEEE-488 Interface (197) 90
1973 IEEE-488 Interface (197) 90
1978 Rechargeable Battery Pack (197).....90
1979 Spare Parts Kit (197) 90

2000
2000 Rack Mounting Kit (427, 642) 90
2243 IEEE-488 Interface (224) 90
2288 Fixed Rack Mounting Kit (228, 590) 90
2289A Slide Rack Mounting Kit (228, 590) 90
2503 Static Detector Probe 90

4000
4003A Rack Mounting Kit (225, 261, 26000)..................91
4801 Low Noise Input Cable 91
4802-10 Low Noise Input Cable 91
4803 Low Noise Cable Kit...............91
4804 Adapter 91
4851 BNC Shorting Plug 91

5000
5801 Test Lead Pouch...................91
5802 IEEE-488 Interface/Analog Output (580) 91
5804 Test Lead Set (4-Wire) 91
5805 Kelvin Probes 92
5806 Kelvin Clip Lead Set...............92
5904 20nF/20mS Adapter (590) 92
5905 Calibration Sources (590)...........92
5906 Calibration Sources (590)...........92
5907 Calibration Sources (590)...........92
5955 Calibration Sources (595)...........92

6000
6011-3 Input Cable, 0.9m (3 ft.) 92
6011-10 Input Cable, 3m (10 ft.) 92
6012 Triax to UHF Adapter.............93
6101A Shielded Test Lead 93
6103C Voltage Divider Probe 93
6104 Shielded Test Fixture 93
6105 Resistivity Chamber 93
6146 Triax Tee Adapter 93
6147 Triax to BNC Adapter.............93
6167 Guarded Input Adapter............94
6171 Triax Adapter 94
6172 Triax Adapter 94
6191 Input Adapter.....................94
6193 IEEE-488 Interface (619) 94
6194 Electrometer Module (619) 94
6195 Maintenance Kit (619)..............94
6421 Desiccant Paper Refill (642).........94
6422 Isolated BCD Output (642) 94
6423 Isolated IEEE-488 Output (642) 94
6424 BNC Adapter (642) 95
6425 Input Adapter (642) 95
6426 Sapphire-Insulated Test Box (642) ...95
6427-20 Interconnect Cable, 20 ft. (642)....95
6427-50 Interconnect Cable, 50 ft. (642)....95
6428 Battery Adapter (642) 95

Index

7000
7007-1 Shielded IEEE-488 Cable, 1m 95
7007-2 Shielded IEEE-488 Cable, 2m 95
7008-3 IEEE-488 Digital Cable, 0.9m (3 ft.) . 95
7008-6 IEEE-488 Digital Cable, 1.8m (6 ft.) . 95
7010 IEEE-488 Adapter 95
7023 Female Triax Adapter 95
7024-3 Triax Cable, 0.9m (3 ft.) 96
7024-10 Triax Cable, 3m (10 ft.) 96
7051-2 BNC to BNC Cable, 0.8m (2 ft.) 96
7051-5 BNC to BNC Cable, 1.6m (5 ft.) 96
7052 5×4 Matrix Switching Card 77
7053 High Current Switching Card 77
7054 High Voltage Switching Card 77
7056 General Purpose Switching Card .. 78
7057A Thermocouple Switching Card 78
7058 Low Current Switching Card 79
7059 Low Voltage Switching Card 79
7061 Universal Adapter Switching Card . 80
7062 RF Switching Card 80
7063 RF Switching Card 80
7064 20-Channel Low Voltage
Switching Card 80
7065 Hall Effect Switching Card 83
7066 Relay Switching Card 81
7067 4-Wire Switching Card 81
7068 Fixed Rack Mounting Kit (706) 96
7069 Slide Rack Mounting Kit (706) 96
7158 Low Current Switching Card 82
7168 Nanovolt Switching Card 82
7401 Type K Thermocouple Wire Kit 96
7402 Thermocouple Switching Card 78
7754-3 BNC to Alligator Cable 96
7755 50Ω Feed-Through Terminator 96

8000
8000 Equipment Cabinet 96
8001 Semiconductor Test Fixture 96
8002 High Resistance Test Fixture 97
8003 Low Resistance Test Fixture 97
8691 RTD Connector Kit 97
8693 RTD General Purpose Probe 97
8695 RTD Surface Probe 97
8696 RTD Air/Gas Probe 97

18000
18000-20 Log Picoammeter 48

19000
19072 Input Cable 97

20000
26000 Log Picoammeter 48

30000
32418 UHF-MHV Cable 97

A
Accessories 85
ADM1 A/D Module 108
ADM2 A/D Module 108
AIM1 Analog Input Module 109
AIM2 Analog Input Module 109
AIM3 Analog Input Module 110
AIM4 Analog Input Module 110
AIM5 Analog Input Module 111
AIM6 Analog Input Module 111
AIM7 Analog Input Module 112
AIM8 Analog Input Module 113
AIM9 Analog Input Module 114
AMM1 Master Measurement Module 107
AOM1 Analog Output Module 115
AOM2 Analog Output Module 115
AOM3 Analog Output Module 116
AOM4 Analog Output Module 116
ASYST Data Acquisition Software 142
ASYSTANT Data Acquisition Software ... 143

C
CA-18-1 Shielded Cable 97
CS-115 UHF-BNC Adapter 97
CS-141 Male Triaxial Cable Mount
Connector 97

D
DADiSP Data Acquisition Software 138
Data Acquisition & Control Division 98
Digital Multimeters 4
DIM1 Digital Input Module 117
DIO1 Digital Input/Output Module 117
DOM1 Digital Output Module 118

E
Electrometers 31
EXTEND Extender Module 121

G
GPIB IEEE-488 Controller Module 124

H
Hall Effect Measurements 83

L
Lab I/O Data Acquisition Software 137
Labtech Notebook Data Acquisition
Software 140

M
Milli-ohmmeter 25

N
Nanovoltmeters 58

O
Ordering Information 153

P
PCM1 Power Control Module 118
PCM2 Power Control Module 119
PCM3 Power Control Module 119
Picoammeters 31
PIM1 Frequency Input Module 120
PIM2 Event Counting Module 120
PROTO Prototyping Module 121

Q
Quick500 Data Acquisition Software 136

R
Radiation Measurements Division 148

S
Sales Representatives, Europe 156
Sales Representatives, International 155
Sales Representatives, U.S. 154
SC-9 Coaxial Cable 97
SC-22 Triaxial Cable 97
Series 500 Data Acquisition System 102
Service Information 153
Soft500 Data Acquisition Software 132
Sources, Current & Voltage 64
STEP1 Stepper Motor Controller
Module 126
STEP2 Stepper Motor Controller
Module 126
Substitution List 152
Switching Cards 76
System 570 Data Acquisition
Workstation 104
Systems Division 146

Substitution Chart, Technical Literature

Obsolete/Replacement Equipment; Free Technical Literature

The following is a list of obsolete Keithley products and suggested replacement models. To ensure adequate replacement, please review the replacement instrument's specifications in this catalog. If the suggested replacement does not meet specific application requirements or if the obsolete model is not listed, contact Keithley Applications Department or your local Keithley representative for assistance.

Obsolete Models	Description	Suggested Replacements
140, 147, 148, 149, 150A, 150B, 180	Nanovoltmeters/Null Detectors	181
151, 151C, 153	Microvoltmeters/Null Detectors	155
160, 163, 164, 171, 172, 172A, 173	DMMs	175, 177, 197
165, 167, 168	DMMs	169, 175
174, 192	DMMs	196
195, 195T	DMMs	195A
176, 178, 179, 179-20A	4½-Digit DMMs	175, 179A
190, 191	5½-Digit DMMs	197
200, 200A, 200B, 210	Electrometer Voltmeters	614
225*	Current Source	220
240, 240A, 241, 242, 243, 244, 245, 246	High Voltage Supplies	247
250	Static Meter	610C with 2503
260	Nanovolt Source	262
409, 410A, 411, 414A, 414S, 415	Picoammeters	480, 485, 614
412, 413	Log Picoammeters	485, 26000
416, 417	High Speed Picoammeters	427 with 196
502, 502A, 503, 600, 600A, 600B, 620, 621	Electrometers	614, 617
601	Electrometer	602
610, 610A, 610B	Electrometers	610C, 617
615, 616	Electrometers	617
640	Electrometer	642
660, 660A, 661,662	Differential Voltmeters	193A, 195A, 196, 197
702	Scanner	705
703	Scanner	706
1641	Kelvin Clips	5806
5900, 6900, 192*, 193	System DMMs	193A, 195A, 196
8573, 8573A	IEEE-488 Interface Card	PC-488-CEC

*These models available at catalog date. Contact Keithley Applications Department or your local representative to determine availability.

Free Technical Literature (Contact Keithley Applications Department or your local Keithley representative.)

- **Brochures/Technical Supplements**—Some of our more sophisticated instruments have additional information available upon request.
- **Programming Guides**—These pocket size booklets are extremely useful when programming any of our IEEE-488 compatible instruments.
- **New Product Information**—Contact us any time concerning information on our latest instruments.
- **Experiments**—Two sets of experiments for Electronics and Physics laboratory use are available to educational institutions.

Application Notes

100 Low Current Measurements
120 Capacitor Leakage Measurements
200 Understanding Low Voltage Measurements
290 Static Charge Measurements
301 Automating Low Resistance Measurements
311 Automating High Resistance Measurements
401 Specifying Temperature Measuring Systems
610 Designing Software Using State Table Driven Code
700 Switching in Multipoint Testing
710 Guarding vs Isolation in DMMs
800 Plus500 Instrument Control System
801 Triggers
802 Low DC Voltage Measurements
803 Formatting Instrumentation Data for LOTUS 1-2-3, ASYST™, and DADiSP II
804 Comparing Data Acquisition Software for Personal Computers
805 Choosing PC-Based Data Acquisition Hardware
806 Using a Personal Computer for Laboratory Recording
807 Titration
808 Utilizing IEEE-488 Translator
809 Combining Data Acquisition and GPIB Control
810 PC-Based Replacement of the Laboratory Record (Oscillograph)
Low Level Measurements Handbook

The precision measurement instruments made by Keithley are widely recognized for the quality, performance, and reliability they offer at affordable prices. We're proud of the recognition that our products have received. However, there's more to our success. We believe that our superior customer service has benefited our growth.

Applications
For technical assistance with your specific needs and problems, contact your local sales representative or our in-house applications engineers.

Manuals
Our Technical Manuals Department is dedicated to seeing that the customer is provided with the best possible information needed to operate and maintain Keithley products.

Each product is supplied with an instruction manual containing operating instructions, performance verification procedures, and descriptions of available optional accessories. Also included in the manual is such detailed information as theory of operation, troubleshooting and calibration procedures, schematics, and component layouts.

Repair and Calibration Services
Keithley Instruments maintains a complete repair and calibration service as well as a standards laboratory in Cleveland, Ohio and Munich, West Germany. Service is also available at regional authorized repair/calibration facilities. Contact Keithley Instruments for the address of service facilities nearest you.

To ensure prompt repair or recalibation service, please contact your local field representative or Keithley headquarters directly before returning the instrument. Repair prices, normal recalibrations and calibrations traceable to the National Bureau of Standards are available upon request.

Service Seminars
Keithley occasionally provides seminar training programs on servicing your Keithley equipment. If you are interested in attending a seminar, contact our repair department.

Demonstrations
If your application requires that you evaluate an instrument before you purchase it, a hands-on demonstration can be arranged by contacting your local Keithley representative or the Sales Department at Corporate Headquarters.

Order and Quotation Information

Pricing and Terms
Your local Keithley representative will gladly furnish price quotations. Specifically, these guidelines apply to orders and quotations placed within the geographical areas outlined below.

Our allocations department is responsible for expediting orders and allocating finished goods. Parts orders are expedited through the repair department.

Keithley is committed to personalized service. Whatever your needs are, your requests will be handled quickly and efficiently by qualified Keithley personnel.

United States and Its Territories

Prices: All prices are F.O.B. Cleveland, Ohio. Transportation charges, insurance, and special handling are extra.

Terms: ½% 10 days, net 30 days (subject to prior approval).

Shipment: Unless otherwise specified, goods will be sent insured freight prepaid and added to invoice. Other shipping instructions will be followed on request.

Canada, Asia and the Far East, Latin America, Australia, New Zealand, and South Africa

Prices: Prices in these areas of the world are F.O.B. factory, Cleveland, Ohio. Forwarding, duties, transportation, insurance and other applicable fees are extra. C & F or CIF proforma invoices are available on request.

Terms: Available on request.

Shipment: Unless otherwise specified, goods will be sent collect via air insured. Other shipping instructions will be followed on request.

Europe, North Africa, and the Middle East

Prices: An exclusive price list is available on request. These prices ar F.O.B Geneva and Switzerland. Transportation from Geneva, insurance, and other charges are extra. Consult your local representative or European Headquarters.

Terms: Available on request.

Shipment: Goods will be sent collect via surface insured. Other shipping instructions will be followed on request.

Where To Send Orders

U.S.A. and other countries outside of Europe, North Africa, and the Middle East

Send orders to your Keithley representative or U.S. Corporate Headquarters. Prices and specifications are subject to change without notice.

Europe, North Africa, and the Middle East

Send orders to your Keithley representative or European Headquarters.

Warranty

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley Headquarters in Cleveland, Ohio. You will be given prompt assistance and shipping instructions. (Note: This warranty does not cover battery replacement or damage caused by battery leakage; certain accesories carry a 90 day warranty.)

U.S.A./Sales Representatives

U.S. HEADQUARTERS
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400
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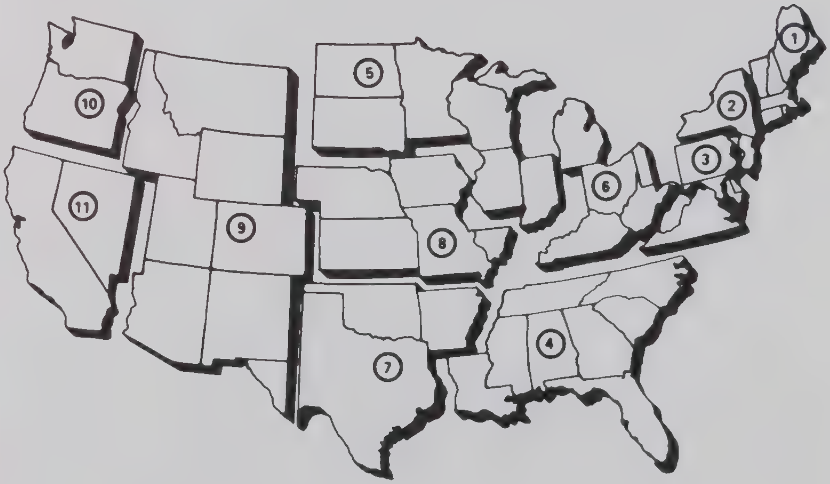

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☐ Set of Physics Experiments*
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INSTRUMENTS & DATA ACQUISITION PRODUCTS

Effective April 1, 1987

INSTRUMENT PRODUCTS

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT		FOR RACK CONVERSION USE MODEL:
			kg	lbs.	
1004B	Rack Mounting Kit, Single Unit (brown)	185.00	3.2	7	
1007	Dual Rack Mounting Kit for 427, 642	99.00	0.4	1	
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1019S-1	5¼ in. Single Slide Rack Mounting Kit	195.00	11.0	23	
1019S-2	5¼ in. Dual Slide Rack Mounting Kit	195.00	11.0	23	
1301	Temperature Probe	99.00	0.4	1	
1481	Low Thermal Input Cable with Clips (4 ft.)	195.00	0.4	1	
1482	Low Thermal Input Cable with Unterminated Leads (10 ft.)	195.00	0.4	1	
1483	Low Thermal Connection Kit	450.00	2.3	5	
1484	Refill Kit for 1483 Kit	195.00	0.9	2	
1485	Female Low Thermal Input Connector	140.00	0.4	1	
1486	Male Low Thermal Input Connector	140.00	0.4	1	
1488	Low Thermal Shorting Plug	195.00	0.4	1	
1489	Replacement Battery Pack for 148	195.00	1.4	3	
1506	Low Thermal Input Cable (4 ft., Clips)	199.00	0.4	1	
1507	Low Thermal Input Cable (4 ft., Lugs)	175.00	0.4	1	
155	Null Detector/Microvoltmeter	**1795.00**	4.1	9	
1600A	High Voltage Probe	85.00	0.4	1	
1651	50-Ampere Shunt	55.00	0.4	1	
1681	Clip-On Test Lead Set	15.00	0.4	1	
1682A	RF Probe	69.00	0.4	1	
1683	Universal Test Lead Kit	18.00	0.4	1	
1684	Hard Shell Carrying Case for Bench DMMs	75.00	2.7	6	
1685	Clamp-On Current Probe	105.00	0.9	2	
1686	Vinyl Carrying Case	35.00	0.9	2	
169	Portable/Bench LCD DMM w/Test Leads and C-Zn Batteries (3½ digit)	**210.00**	2.8	6	..1010, 1017
1691	General Purpose Test Leads	10.00	0.4	1	
1699	Spare Parts Kit for 169	50.00	0.4	1	
169/1766	Portable/Bench LCD DMM with Battery Eliminator installed	**265.00**	2.8	6	..1010, 1017
1766	Battery Eliminator for 169	60.00	0.4	1	
175	Autoranging Digital Multimeter (4½ digit)	**449.00**	1.8	4	..1010, 1017
1751	Safety Test Leads	15.00	0.4	1	
1753	IEEE-488 Interface for 175	225.00	1.3	3	
1754	Safety Universal Test Lead Kit	25.00	0.4	1	
1755	Calibration Interface for 175, 197, 485, 580	400.00	1.8	4	
1758	Rechargeable Battery Pack for 175, 485	79.00	0.9	2	
1759	Spare Parts Kit for 175	57.00	0.4	1	
175/1753	Autoranging Multimeter with IEEE-488 Interface	**674.00**	3.2	7	..1010, 1017
175/1758	Autoranging Multimeter with Rechargeable Battery Pack	**528.00**	2.8	6	..1010, 1017
175/53/58	Autoranging Multimeter with IEEE-488 Interface and Battery Pack	**753.00**	4.0	9	..1010, 1017
177	Microvolt Digital Multimeter (4½ digit)	**595.00**	2.8	6	..1010, 1017
1779	Spare Parts Kit for 177	89.00	0.4	1	
177/1788	Microvolt Digital Multimeter with Rechargeable Battery Pack	**745.00**	4.5	10	..1010, 1017
177/1792	Microvolt Digital Multimeter with BCD Output	**794.00**	4.0	9	..1010, 1017
177/1793	Microvolt Digital Multimeter with IEEE-488 Output	**920.00**	4.0	9	..1010, 1017
1788	Rechargeable Battery Pack for 177, 179A, 480	150.00	0.9	2	
179A	TRMS Digital Multimeter, 20 Amp w/Test Leads (4½ digit)	**470.00**	2.8	6	..1010, 1017
1792	Isolated BCD Output for 177, 179A, 480	199.00	1.4	3	
1793	Isolated IEEE-488 Output for 177, 179A, 480	325.00	1.4	3	
1796	Mating Cable, 1792 to Unterminated (10 ft.)	30.00	0.4	1	
179A/1788	TRMS Digital Multimeter with Rechargeable Battery Pack	**620.00**	4.5	10	..1010, 1017
179A/1792	TRMS Digital Multimeter with BCD Output	**669.00**	4.0	9	..1010, 1017
179A/1793	TRMS Digital Multimeter with IEEE-488 Output	**795.00**	4.0	9	..1010, 1017
18000-20	High Speed Programmable Current Amplifier	**1695.00**	0.9	2	
181	Digital Nanovoltmeter	**3195.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
1815	Maintenance Kit for 181	99.00	0.4	1	

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT kg	lbs.	FOR RACK CONVERSION USE MODEL:
192	Programmable DMM (5½-6½ digit)	**1395.00**	5.0	11	..1019A-1, 1019A-2, 1019S-1, 1019S-2
1910	Averaging AC Volts Option for 192	240.00	0.4	1	
1920	True RMS AC Volts Option for 192	310.00	0.4	1	
1923A	IEEE-488 Interface for 192	415.00	0.4	1	
1924	Rear Input Adapter for 192	375.00	0.4	1	
192/1910	Programmable DMM with Averaging AC Volts	**1635.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
192/1920	Programmable DMM with TRMS AC Volts	**1705.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
192/1923	Programmable DMM with 1923A IEEE-488 Interface	**1810.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
192/10/23	Programmable DMM with Averaging AC Volts and 1923A IEEE-488 Interface	**2050.00**	5.8	13	..1019A-1, 1019A-2, 1019S-1, 1019S-2
192/20/23	Programmable DMM with TRMS AC Volts and 1923A IEEE-488 Interface	**2120.00**	5.8	13	..1019A-1, 1019A-2, 1019S-1, 1019S-2
193A	System DMM (3½-6½ digit)	**2195.00**	4.5	15	..1938, 1939
1930	TRMS ACV Option for 193A	300.00	0.4	1	
1931	Current Option for 193A	200.00	0.4	1	
1938	Fixed Rack Mounting Kit for 193A, 194A	90.00	1.4	3	
1939	Slide Rack Mounting Kit for 193A, 194A	185.00	3.0	7	
193A/1930	System DMM with TRMS AC Volts (3½-6½ digit)	**2495.00**	4.5	16	..1938, 1939
193A/1931	System DMM with Current Option (3½-6½ digit)	**2395.00**	4.5	16	..1938, 1939
193A/30/31	System DMM with TRMS AC Volts and Current Option	**2695.00**	8.0	17	..1938, 1939
194A	High Resolution Digitizer	**4095.00**	12.0	26	..1938, 1939
1942	External Sample Trigger Cable	75.00	0.4	1	
1944A	Second Channel for 194A	1995.00	1.8	4	
194A/1944A	Dual Channel High Resolution Digitizer	**6090.00**	13.5	29	..1938, 1939
195A	System DMM with Temperature (4½-5½ digit)	**995.00**	5.0	11	..1019A-1, 1019A-2, 1019S-1, 1019S-2
1950	DCA, TRMS ACV and ACA Option for 195A	325.00	0.4	1	
1951	Platinum RTD Adapter for 195A	80.00	0.4	1	
195A/1950	System DMM with Temperature, DCA, TRMS ACV and ACA	**1320.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
196	System DMM (3½-6½ digit)	**1395.00**	5.9	13	1019A-1,1019A-2 1019S-1,1019S-2
197	Autoranging Microvolt Digital Multimeter (5½ digit)	**595.00**	3.2	7	..1010, 1017
1972	IEEE-488 Interface with Analog Output for 197	300.00	0.5	1	
1973	IEEE-488 Interface for 197	225.00	0.5	1	
1978	Rechargeable Battery Pack for 197, 580	99.00	1.0	2	
1979	Spare Parts Kit for 197	100.00	0.4	1	
197/1972	Autoranging Microvolt DMM w/IEEE-488 & Analog Output	**895.00**	3.7	8	..1010, 1017
197/1973	Autoranging Microvolt DMM w/IEEE-488 Interface	**820.00**	3.7	8	..1010, 1017
197/1978	Autoranging Microvolt DMM w/Rechargeable Battery Pack	**694.00**	4.1	9	..1010, 1017
197/72/78	Autoranging Microvolt DMM w/IEEE-488, Analog Output, Battery Pack	**994.00**	4.6	10	..1010, 1017
197/73/78	Autoranging Microvolt DMM w/IEEE-488 and Battery Pack	**919.00**	4.6	10	..1010, 1017
2000	Single Rack Mounting Kit for 427 and 642	90.00	0.9	2	
220	Programmable Current Source with IEEE-488 Interface	**3195.00**	7.3	16	..1019A-1, 1019A-2, 1019S-1, 1019S-2
224	Programmable Current Source	**2295.00**	5.0	11	..1019A-1, 1019A-2, 1019S-1, 1019S-2
2243	IEEE-488 Interface for 224	315.00	0.4	1	
224/2243	Programmable Current Source with IEEE-488 Interface	**2610.00**	7.3	16	..1019A-1, 1019A-2, 1019S-1, 1019S-2
225	Current Source	**2995.00**	5.9	13	..1004
228	Programmable Voltage/Current Source w/IEEE-488 Interface	**3395.00**	10.9	24	..2288, 2289A
2288	Fixed Rack Mounting Kit for 228	90.00	1.4	3	
2289A	Slide Rack Mounting Kit for 228	185.00	3.0	7	
230	Programmable Voltage Source with IEEE-488 Interface	**2180.00**	4.5	10	..1019A-1, 1019A-2, 1019S-1, 1019S-2
247	Regulated High Voltage Supply (bench/rack)	**1295.00**	7.2	16	
2503	Static Detector Probe	415.00	0.9	2	
261	Picoampere Source	**2495.00**	5.4	12	..4003A
262	Nanovolt Low Thermal Voltage Divider	**1695.00**	3.2	7	

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT		FOR RACK CONVERSION USE MODEL:
			kg	lbs.	
26120	Log Picoammeter (10^{-3} to 10^{-11}A)	**2995.00**	5.9	13	..1004B
26220	Log Picoammeter (10^{-4} to 10^{-12}A)	**3195.00**	5.9	13	..1004B
26320	Log Picoammeter (10^{-7} to 10^{-13}A)	**3395.00**	5.9	13	..1004B
4003A	Single Rack Mounting Kit for 261	175.00	1.8	4	
427	Current Amplifier	**2295.00**	5.0	11	..1007, 2000
480	Digital Picoammeter	**750.00**	2.7	6	..1010, 1017
4801	Low Noise BNC Input Cable, 4 ft.	45.00	0.4	1	
4802-10	Low Noise BNC Input Cable, 10 ft. (unterminated)	50.00	0.4	1	
4803	Low Noise Cable Kit	65.00	1.4	3	
4804	Male BNC to Female Triax Adapter	120.00	0.4	1	
480/1788	Digital Picoammeter with Rechargeable Battery Pack	**900.00**	4.5	10	..1010, 1017
480/1793	Digital Picoammeter with IEEE-488 Output	**1075.00**	4.0	9	..1010, 1017
485	Autoranging Digital Picoammeter	**725.00**	1.8	4	..1010, 1017
4851	BNC Shorting Plug	45.00	0.4		
4853	IEEE-488 Interface for 485	225.00	1.4	3	
485/1758	Autoranging Digital Picoammeter with Rechargeable Battery Pack	**804.00**	2.7	6	..1010, 1017
485/4853	Autoranging Digital Picoammeter with IEEE-488 Interface	**950.00**	3.2	7	..1010, 1017
580	Micro-ohmmeter with 5804, 5805, 5806 Test Leads & 5801 Test Lead Pouch	**1495.00**	5.4	12	..1010, 1017
5801	Test Lead Pouch	70.00	0.9	2	
5802	Isolated Analog Output/IEEE-488 Interface	300.00	0.4	1	
5804	Test Lead Set	140.00	0.4	1	
5805	Kelvin Probes	160.00	0.4	1	
5805-12	Kelvin Probes (12 ft.)	195.00	0.4	1	
5806	Kelvin Clip Leads	195.00	0.4	1	
580/5802	Micro-ohmmeter with Isolated Analog Output/IEEE-488 Interface	**1795.00**	5.9	13	..1010, 1017
580/1978	Micro-ohmmeter with Rechargeable Battery Pack	**1594.00**	6.4	14	..1010, 1017
580/02/78	Micro-ohmmeter with Isolated Analog Output/IEEE-488 Interface & Batt. Pack	**1894.00**	6.9	15	..1010, 1017
590/100k	100kHz CV Analyzer	**5990.00**	15.3	34	..2288, 2289A
590/1M	1MHz CV Analyzer	**5990.00**	15.3	34	..2288, 2289A
590/100k/1M	100kHz/1M CV Analyzer	**7990.00**	15.8	35	..2288, 2289A
590/100k/4	100kHz CV Analyzer with Calibrated 5904 Adapter	**6290.00**	15.8	35	..2288, 2289A
590/100k/1M/4	100kHz/1MHz CV Analyzer with Calibrated 5904 Adapter	**8290.00**	16.2	36	..2288, 2289A
5904	20nF/20mS Adapter (not calibrated to mainframe)	250.00	0.4	1	
5905	Calibration Sources for 590/1M	2795.00	2.2	5	
5906	Calibration Sources for 590/100k/1M/4	3695.00	1.4	3	
5907	Cable/Matrix Calibration Sources	995.00	1.4	3	
595	Quasistatic CV Meter	**4995.00**	3.2	7	..1019A-1, 1019A-2, 1019S-1, 1019S-2
5955	Calibration Capacitor Set for 595	1695.00	0.9	2	
602	Solid State Electrometer (battery) with Test Leads	**2850.00**	8.0	17	
6011	Input Leads (5 ft.), Triax to Clips	99.00	0.4	1	
6011-10	Input Leads (10 ft.), Triax to Clips	145.00	0.4	1	
6012	Triax to UHF Adapter	85.00	0.4	1	
610C	Electrometer (bench)	**2995.00**	6.4	14	
6101A	Shield Probe	235.00	0.4	1	
6103C	Voltage Divider Probe (1000:1)	435.00	0.9	2	
6104	Test Shield	535.00	1.4	3	
6105	Resistivity Chamber	995.00	2.3	5	
614	Digital Electrometer	**1595.00**	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
6146	Triax Tee Adapter	50.00	0.4	1	
6147	Male Triax to Female BNC Adapter	85.00	0.4	1	
6167	Guarded Input Adapter for 220, 224, 602, 614	375.00	0.4	1	
617	Programmable Electrometer/Source	**3095.00**	3.6	8	..1019A-1, 1019A-2, 1019S-1, 1019S-2
6171	3-Slot Male to 2-Lug Female Triaxial Adapter	50.00	0.4	1	
6172	2-Slot Male to 3-Lug Female Triaxial Adapter	50.00	0.4	1	
619	Digital Electrometer/Multimeter	**4150.00**	13.0	28	..1019A, 1019S
6191	Guarded Input Adapter for 619	345.00	0.4	1	
6193	IEEE-488 Interface for 619	345.00	0.4	1	
6194	Electrometer Module for 619	1195.00	0.9	2	
6195	Maintenance Kit for 619	450.00	2.3	5	
619/6193	Digital Electrometer/Multimeter with IEEE-488 Interface	**4495.00**	13.5	29	..1019A,1019S
619/93/94	2-Channel Digital Electrometer/Multimeter with IEEE-488 Interface	**5690.00**	14.5	32	..1019A, 1019S,

MODEL	DESCRIPTION		DOMESTIC PRICE	SHIPPING WEIGHT		FOR RACK CONVERSION USE MODEL:
				kg	lbs.	
642	Digital Electrometer (without Input Adapter)		**5995.00**	12.0	26	..1007, 2000
642 LNFPA	Digital Electrometer, $<50\mu$V p-p noise, fast 10^{-11}A range		**7495.00**	12.0	26	..1007, 2000
642 LNFPA/6423	Digital Electrometer $<50\mu$V p-p noise, fast 10^{-11} A Range w/IEEE-488 Output		**7990.00**	13.0	28	..1007, 2000
6421	Desiccant Paper Refill		30.00	1		
6422	Isolated BCD Output for 642		395.00	0.4	1	
6423	Isolated IEEE-488 Output for 642		495.00	0.4	1	
6424	BNC Input Adapter for 642		140.00	0.4	1	
6425	Genrad GR874® Air Line Input Adapter for 642		260.00	0.4	1	
6426	Sapphire Insulated Test Box		795.00	1.4	3	
6427-20	20-foot Interconnect Cable for 642		595.00	2.8	6	
6427-50	50-foot Interconnect Cable with Remote Supply for 642		1495.00	8.0	18	
6428	Battery Adapter for 642		440.00	0.4	1	
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft.)		89.00	0.4	1	
7007-2	Shielded IEEE-488 Cable, 2m (6.5 ft.)		99.00	0.4	1	
7008-3	IEEE-488 Digital Cable, 0.9m (3 ft.)		77.00	0.4	1	
7008-6	IEEE-488 Digital Cable, 1.8m (6 ft.)		77.00	0.9	2	
7010	Shielded IEEE-488 to IEEE-488 Adapter		56.00	0.4	1	
7023	Female Triaxial Connector		26.00	0.4	1	
7024-3	Triaxial Cable, 0.9m (3 ft.)		105.00	0.4	1	
7024-10	Triaxial Cable, 3.0m (10 ft.)		125.00	0.4	1	
7025-10	Low Noise Triaxial Input Cable (one end unterminated, 10 ft.)		85.00	0.4	1	
705	20-Channel Scanner Mainframe (without cards)	1 - 3 units	**995.00** ea.	5.4	12	..1019A-1, 1019A-2, 1019S-1, 1019S-2
		4+ units	**900.00** ea.	5.4	12	
705/7065	20-Channel Scanner Mainframe with Hall Effect Card		**5495.00**	8.6	19	..1019A-1, 1019A-2 1019S-1, 1019S-2
7051-2	BNC Interconnect Cable (2 ft.)	1 - 4 units	30.00 ea.	0.4	1	
		5+ units	25.00 ea.	0.4	1	
7051-5	BNC Interconnect Cable (5 ft.)	1 - 4 units	30.00 ea.	0.9	2	
		5+ units	25.00 ea.	0.9	2	
7052	5×4 Matrix Plug-In Switching Card	1 - 4 units	650.00 ea.	0.9	2	
		5 - 9 units	590.00 ea.	0.9	2	
		10 - 19 units	525.00 ea.	0.9	2	
		20+ units	475.00 ea.	0.9	2	
7053	High Current Plug-In Switching Card	1 - 4 units	525.00 ea.	0.9	2	
		5 - 9 units	480.00 ea.	0.9	2	
		10 - 19 units	440.00 ea.	0.9	2	
		20+ units	420.00 ea.	0.9	2	
7054	High Voltage Plug-In Switching Card	1 - 4 units	525.00 ea.	0.9	2	
		5 - 9 units	480.00 ea.	0.9	2	
		10 - 19 units	440.00 ea.	0.9	2	
		20+ units	420.00 ea.	0.9	2	
7055	10-Channel Quick Disconnect (supplied with 7056)	1 - 4 units	99.00 ea.	0.4	1	
		5 - 9 units	92.00 ea.	0.4	1	
		10 - 19 units	83.00 ea.	0.4	1	
		20+ units	80.00 ea.	0.4	1	
7056	General Purpose Relay Plug-In Switching Card w/Quick Disconnect	1 - 4 units	275.00 ea.	0.9	2	
		5 - 9 units	245.00 ea.	0.9	2	
		10 - 19 units	215.00 ea.	0.9	2	
		20+ units	206.00 ea.	0.9	2	
7057A	Thermocouple Plug-In Switching Card	1 - 4 units	630.00 ea.	0.9	2	
		5 - 9 units	595.00 ea.	0.9	2	
		10 - 19 units	550.00 ea.	0.9	2	
		20+ units	525.00 ea.	0.9	2	
7058	Low Current Plug-In Switching Card	1 - 4 units	1195.00 ea.	0.9	2	
		5 - 9 units	1110.00 ea.	0.9	2	
		10 - 19 units	1020.00 ea.	0.9	2	
		20+ units	980.00 ea.	0.9	2	
7059	Low Voltage Plug-In Switching Card	1 - 4 units	515.00 ea.	0.9	2	
		5 - 9 units	470.00 ea.	0.9	2	
		10 - 19 units	425.00 ea.	0.9	2	
		20+ units	400.00 ea.	0.9	2	
706	100 Channel System Scanner Mainframe (without cards)	1 - 3 units	**2095.00** ea.	12.5	27	..7068, 7069
		4+ units	**1895.00** ea.	12.5	27	
7061	Universal Adapter Card		120.00 ea.	0.9	2	

MODEL	DESCRIPTION		DOMESTIC PRICE	SHIPPING WEIGHT kg	SHIPPING WEIGHT lbs.	FOR RACK CONVERSION USE MODEL:
7062	RF Switching Card (unterminated)	1 - 4 units	465.00 ea.	0.9	2	
		5 - 9 units	440.00 ea.	0.9	2	
		10 - 19 units	410.00 ea.	0.9	2	
		20+ units	395.00 ea.	0.9	2	
7063	RF Switching Card (terminated)	1 - 4 units	655.00 ea.	0.9	2	
		5 - 9 units	615.00 ea.	0.9	2	
		10 - 19 units	570.00 ea.	0.9	2	
		20+ units	550.00 ea.	0.9	2	
7064	20-Channel Low Voltage Switching Card	1 - 4 units	695.00 ea.	0.9	2	
		5 - 9 units	650.00 ea.	0.9	2	
		10 - 19 units	605.00 ea.	0.9	2	
		20+ units	585.00 ea.	0.9	2	
7065	Hall Effect Card including Accessories		4995.00	3.2	7	
7066	Relay Switching Card	1 - 4 units	315.00 ea.	0.4	1	
		5 - 9 units	285.00 ea.	0.4	1	
		10 - 19 units	250.00 ea.	0.4	1	
		20+ units	235.00 ea.	0.4	1	
7067	Four Wire Scanner Card	1 - 4 units	630.00 ea.	0.9	2	
		5 - 9 units	592.00 ea.	0.9	2	
		10 - 19 units	573.00 ea.	0.9	2	
		20+ units	561.00 ea.	0.9	2	
7068	Fixed Rack Mounting Kit for 706		90.00	1.4	3	
7069	Slide Rack Mounting Kit for 706		185.00	3.2	7	
7158	Low Current Card	1 - 4 units	950.00 ea.	0.9	2	
		5 - 9 units	874.00 ea.	0.9	2	
		10 - 19 units	836.00 ea.	0.9	2	
		20+ units	817.00 ea.	0.9	2	
7168	Nanovolt Scanner Card	1 - 3 units	1995.00 ea.	1.4	3	
		4+ units	1795.00 ea.	1.4	3	
740	System Scanning Thermometer		**1350.00**	4.0	9	1019A-1, 1019A-2 1019S-1, 1019S-2
740/7402	Scanning Thermometer with 9 Input Channels		**1750.00**	4.7	10	1019A-1, 1019A-2 1019S-1, 1019S-2
7401	Thermocouple Wire Kit (100 ft., Type K)		105.00	0.4		
7402	Thermocouple Scanner Card	1 - 4 units	500.00 ea.	0.9	2	
		5 - 9 units	440.00 ea.	0.9	2	
		10 - 19 units	415.00 ea.	0.9	2	
		20+ units	400.00 ea.	0.9	2	
775A	Programmable Counter/Timer		**1540.00**	3.5	8	1019A-1, 1019A-2 1019S-1, 1019S-2
7754-3	BNC to Alligator Cable (3 ft.)		18.00	0.4	1	
7755	50Ω Feed-Through Terminator		40.00	0.4	1	
775A/51/52	Programmable Counter/Timer with Channel C and TCXO		**1950.00**	4.0	8	1019A-1, 1019A-2, 1019S-1, 1019S-2
8000	Equipment Cabinet, 28 in. high × 19 in. wide × 21 in. deep		745.00	29.5	65	
8001	Semiconductor Test Box with Cables		995.00	1.8	4	
8002	High Resistance Test Box with Cables		695.00	1.8	4	
8003	Low Resistance Test Box with Cables		695.00	1.8	4	
8691	Pt RTD Connector Adapter Kit for 195A		55.00	0.4	1	
8693	Pt RTD General Purpose Probe for 195A		99.00	0.4	1	
8695	Pt RTD Surface Probe for 195A		135.00	0.4	1	
8696	Pt RTD Air/Gas Probe for 195A		135.00	0.4	1	
8711A	Type K Thermocouple Kit		60.00	0.4	1	
8712	Type K Thermocouple Sensor		20.00	0.4	1	
8721	Type J Thermocouple Kit		60.00	0.4	1	
8722	Type J Thermocouple Sensor		20.00	0.4	1	
Package 68	Nanovolt Scanner Package Includes: Model 705 Scanner, Model 7168 Nanovolt Scanner Card, and Model 181 Digital Nanovoltmeter		**5990.00**	12.2	27	
Package 80	Hall Effect Package Includes: Model 705 Scanner, Model 7065 Hall Effect Card, Model 196 System DMM, Model 220 Programmable Current Source, Model 485/4853 Picoammeter, and Model 7008-3 IEEE Cables (3)		**9900.00**	26.1	58	
PC-488-CEC	IEEE-488 Interface Card for IBM PC/XT/AT		**395.00**	0.9	2	
PC-488-COP	Cooperator™ Software; Interactive Programming Aid with PC-488-CEC		**95.00**	0.4	1	
PC-488-INT	Basic Interrupt Handling Software with PC-488-CEC		**95.00**	0.4	1	

DATA ACQUISITION & CONTROL PRODUCTS

The Keithley Series 500 is a modular, user-configured data acquisition and control system. The six pre-configured systems listed below are starter systems. Additional modules can be purchased and added to Series 500 systems in any combination. Pre-configured systems may not be downgraded through omission of certain modules. All Series 500 systems include the mainframe and modules; the SOFT500 software language; two volumes of documentation, including tutorials, schematics, and calibration information; and an interface card for the host computer. The Series 500 and System 570 come with a one-year parts and labor warranty and 90 days of free product applications support. For a formal quotation and current delivery schedule, please contact us at **1-800-552-1115**. Foreign prices may be obtained by consulting our international representatives.

SYSTEMS

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT	
			kg	lbs.
500-500	**System 500 (IBM & 100% Compatibles)†‡** Includes: Mainframe, Interface & Cable	1600.00	13.6	30
500-501	**System 501 (IBM & 100% Compatibles)†‡** Includes: Mainframe, Interface, 500-AMM1 & 500-DIO1	2590.00	13.1	29
500-502	**System 502 (IBM & 100% Compatibles)†‡** Includes: Mainframe, Interface, 500-AIM1, 500-ADM2 & 500-DIO1	3800.00	14.6	31
500-570	**System 570 (IBM & 100% Compatibles)†‡** Data Acquisition Workstation	1425.00	5.0	11
500-570D	**System 570 + DADiSP I (IBM PC, XT only)‡** Includes: Data Acquisition Workstation & Spreadsheet Software Module	1975.00	5.9	13
500-570R	**System 570 + AIM8 + RTMDS†‡** Includes: 4-Channel Strain Gage Module & Real Time Monitoring Card with RTMDS Software. (570 Interface & RTM Card occupy two slots in PC)	3550.00	10.4	23

MODULES

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT	
			kg	lbs.
500-AMM1	*AMM1 8-Channel s/e Master Measurement Module w/12-Bit A/D	660.00	0.4	1
500-AIM1	*AIM1 16-Channel (8 Differential) Analog Input Module	660.00	0.4	1
500-AIM2	AIM2 32-Channel s/e High Level Analog Input Module	440.00	0.4	1
500-AIM3	AIM3 32-Channel (16 Differential) High Sensitivity Analog Input Module	770.00	0.4	1
500-AIM4	AIM4 4-Channel Isolated Analog Input Module	910.00	0.4	1
500-AIM5	AIM5 4-Channel Isolated Low Level Analog Input Module	960.00	0.4	1
500-AIM6	AIM6 4-Channel RTD Analog Input Module	825.00	0.4	1
500-AIM7	AIM7 16-Channel Thermocouple Input Module	960.00	0.4	1
500-AIM8	AIM8 4-Channel Strain Gage Analog Input Module	985.00	0.4	1
500-AIM9	AIM9 2-Channel LVDT/RVDT Analog Input Module	935.00	0.4	1
500-ADM1	*ADM1 12-Bit Analog to Digital Module	910.00	0.4	1
500-ADM2	*ADM2 14-Bit High Resolution Analog to Digital Module	1210.00	0.4	1
500-AOM1/2	AOM1/2 12-Bit D/A, 2-Channel Analog Output Module	690.00	0.4	1
500-AOM1/5	AOM1/5 12-Bit D/A, 5-Channel Analog Output Module	1070.00	0.9	2
500-AOM2/1	AOM2/1 16-Bit D/A, 1-Channel High Resolution Analog Output Module	1100.00	0.4	1
500-AOM2/2	AOM2/2 16-Bit D/A, 2-Channel High Resolution Analog Output Module	1760.00	0.4	1
500-AOM3	AOM3 4-Channel Current Loop Output Module	1020.00	0.4	1
500-AOM4	AOM4 4-Channel Programmable Excitation Output Module	880.00	0.4	1
500-DIM1	DIM1 16-Channel Isolated Digital Input Module	330.00	0.4	1
500-DIO1	DIO1 32-Channel TTL Digital Input/Output Module	330.00	0.4	1
500-DOM1	DOM1 16-Channel Isolated Digital Output Module	330.00	0.4	1
500-EXTEND	Module Extender Board	100.00	0.4	1
500-GPIB	IEEE-488 Instrument Controller Interface Module	650.00	0.4	1
500-PCM1	PCM1 4-Channel AC Power Control Module (includes 4 ea. 500-OAC1)	440.00	0.9	2
500-PCM2	PCM2 16-Channel AC/DC Power Control & Sensing Module (no relays)	630.00	1.3	3
500-PIM1	PIM1 8-Channel Frequency Measurement Module	690.00	0.4	1
500-PIM2	PIM2 4-Channel Event Counting Module	500.00	0.4	1
500-PROTO	Prototyping Module	120.00	0.4	1
500-STEP1	*STEP1 µP Stepper Motor Controller Module	545.00	0.4	1
500-STEP2	*STEP2 1-Channel Stepper Motor Indexer Module	545.00	0.4	1

†Contact factory for a listing of compatible computers.
‡Includes SOFT500, Software Manual & Hardware Manual.
*Not for use in System 570.

SOFTWARE

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT kg	lbs.
500-DADiSP-1	DADiSP I: Spreadsheet Module	700.00	1.3	3
500-DADiSP-2	DADiSP II: Worksheet Module	800.00	1.3	3
500-UKIT	SOFT500 Software Upgrade Kit	55.00		varies
500-HELP-I	Help and Diagnostics Diskettes for IBM PC-Based Systems	55.00	0.4	1
500-QUICK	Compilable Version of SOFT500	495.00	2.2	5
500-LABIO	C Drivers for SOFT500	495.00	2.2	5
500-LABTECH	LABTECH NOTEBOOK® with key (parallel port required)	1045.00	2.2	5
500-RTA	LABTECH REAL-TIME I/O® for Non-Real Time Programs	295.00	2.2	5
500-ASYST123	ASYST-Modules 1,2,3 with key (parallel port required)	2060.00	4.4	10
500-ASYST124	ASYST-Modules 1,2,4 with key (parallel port required)	2060.00	4.4	10
500-ASYST1234	ASYST-Modules 1,2,3,4 with key (parallel port required)	2260.00	4.4	10
500-ASYSTANT	ASYSTANT Ready-to-Run Scientific Software	495.00	2.2	5
500-ASYSTANT+	ASYSTANT Scientific Software & Acquisition Module	895.00	2.2	5
500-RTMDS	Real Time Monitoring & Disk Storage System (with RTM card)	1200.00	5.0	11

ADDITIONAL PRODUCTS

MODEL	DESCRIPTION	DOMESTIC PRICE	SHIPPING WEIGHT kg	lbs.
500-CABL1	IEEE-488 Extension Cable, 1m	77.00	0.4	1
500-CABL2	IEEE-488 Extension Cable, 2m	77.00	0.9	2
500-CABL3	DIO1 Connector Cable	35.00	0.4	1
500-CABL15	System Extension Cable, 15 ft. (for Series 500 only)	80.00	1.3	3
500-OAC1	120V AC Control Relay	25.00	0.4	1
500-OAC2	240V AC Control Relay	25.00	0.4	1
500-IAC1	120V AC Sensing Relay	25.00	0.4	1
500-IAC2	240V AC Sensing Relay	25.00	0.4	1
500-ODC1	60V DC Control Relay	25.00	0.4	1
500-ODC2	200V DC Control Relay	25.00	0.4	1
500-IDC1	32V DC Sensing Relay	25.00	0.4	1
500-IBIN	Series 500 Computer Interface Board for IBM & 100% Compatibles†	770.00	4.1	9
500-MAIN	Series 500 Mainframe (requires computer interface board)	830.00	8.1	18
500-IBMH-1	Additional Series 500 Hardware Manual, IBM & Compatibles	80.00	2.2	5
500-IBMS-1	Additional Soft500 Manual, IBM & Compatibles	80.00	1.8	4
500-TERMS	Spare Quick Disconnect Blocks (4 10-screw and 3 3-screw blocks)	35.00	0.4	1
500-PCM3	PCM3 AC/DC 16-channel Power Control Relay Mounting Board	220.00	1.3	3
500-PROG	Programming Reference Guide, IBM & Compatibles	10.00	0.4	1

COMPATIBILITY

The following computers are compatible with the Series 500 and System 570 hardware: IBM PC, IBM PC/XT, IBM PC/AT, Compaq Portable, Compaq Portable II, Compaq Plus Portable, Compaq DeskPro 286, AT&T 6300, AT&T 6300+, HP Vectra, Leading Edge Model D, NCR PC6, NCR PC8, Sperry IT, ITT Extra XP, and Zenith 240. For companies not listed please contact the factory. RTMDS is not compatible with Compaq Portables, AT&T, or HP Vectra.

These PC's are available with a wide variety of disk drives, memory cards, video adapters, and other accessories. A limited number of configurations enable you to take full advantage of the SOFT500. The following information summarized these configurations.

For IBM PC, XT, and AT:

Recommended DOS: IBM PC-DOS 3.1 or later.
Minimum/Recommended RAM: 512/640K.
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk.
Video Adapter: IBM Color Graphics Adapter, IBM Enhanced Graphics, or Hercules Color Card.

Notes: Compatible with 6MHz and 8MHz AT's.

For Compaq Portable, Portable Plus, and Deskpro 286:

Recommended DOS: Compaq DOS 3.0 or later.
Minimum/Recommended RAM: 512/640.
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk.
Video Adapter: Built-in dual-mode Text-and-Graphics adapter or 100% IBM Compatile CGA or EGA.

Notes: Compatible with Deskpro at both 6MHz and 8MHz. When installed for 6MHz, SOFT500 should not be run at 8MHz, and vice versa.

For 100% IBM Compatible XT and AT Types:

Recommended DOS: Microsoft MS-DOS 3.0 or later.
Minimum/Recommended RAM: 512/640K.
Minimum Disk Drives: 2 floppies, or 1 floppy and 1 fixed disk.
Video Adapter: IBM Color Graphics Adapter, IBM Enhanced Graphics Adapter, or 100%—compatible video adpaters.

Notes: Compatible with AT-type compatibles at both 6MHz and 8MHz. When installed for 6MHz, SOFT500 should not be run at 8MHz, and vice versa.

Notes on PC configurations

1. We have successfully used AST, Quadram, and Persyst boards for memory expansion on IBM PC, XT, AT, and Compaq Portable computers.
2. SOFT500 requires a minimum of 512K RAM to load and run. 640K provides maximum data storage during acquisition and is recommended.
3. Installation of the optional 8087 or 80287 coprocessor increases the speed of execution of SOFT500 commands handling graphics and data arrays.
4. SOFT500 software requires an IBM Color Graphics Adapter, IBM Enhanced Graphics Adapter, or Hercules Color Card (not Hercules Monochrome Graphics) for display of SOFT500 graphics. Other graphics adapters may cause problems. Graphics adapters which make non-standard use of the computer's non-maskable interrupt will not work with SOFT500.
5. The IBM Enhanced Graphics Adapter (EGA) can be used with or without the EGA video memory expansion (256K total video memory).

For quantity prices contact your local representative or Keithley office.

ALL PRICES ARE F.O.B. FACTORY, CLEVELAND, OHIO.

Terms: ½% 10, net 30 days.

Interest will be charged at the rate of 1½% per month or 18% per year on the balance unpaid after 30 days.

Prices and specifications are subject to change without notice.

Instruments and/or apparatus returned to Keithley due to improper selection by the user will be subject to a restocking charge if not returned within 30 days.

For prices of instruction manuals, repair, calibration, and replacement parts, please contact Keithley headquarters in Cleveland, Ohio.

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and shipping instructions. (NOTE: This warranty does not cover battery replacement or damage caused by battery leakage; certain accessories carry a 90-day warranty.)

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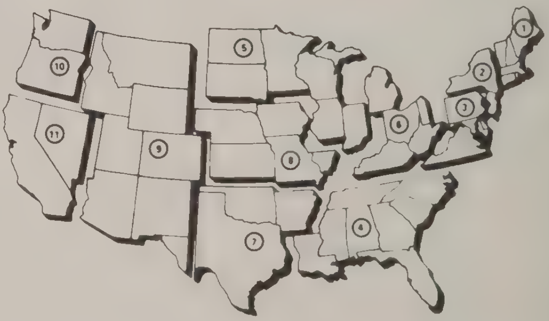

KEITHLEY

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